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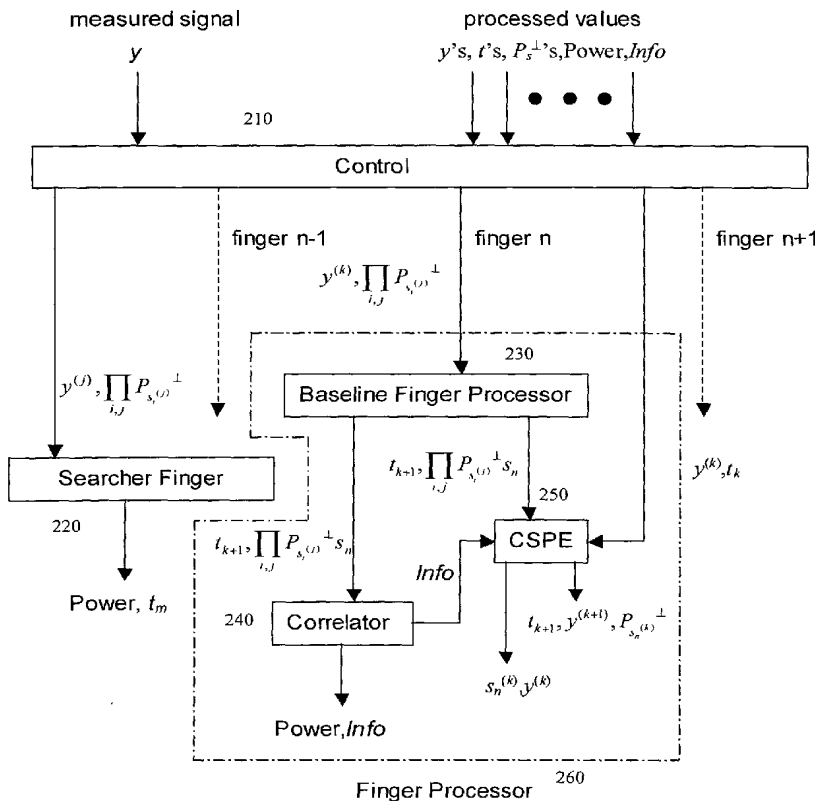
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(54) Title: SERIAL CANCELLATION RECEIVER DESIGN FOR A CODED SIGNAL PROCESSING ENGINE



(57) Abstract: A novel serial receiver for a wireless communication system is provided. The communication system comprises: a receiver for receiving a signal y having data parameters; a control processor; the control processor for receiving the signal y and the data parameters; at least two fingers, the control processor for determining which of the data parameters are sent to respective fingers, wherein the at least two fingers have at least a search finger and a tracking finger; and wherein the tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), the CSPE for interference cancellation in the reception of the signal y . In addition, numerous other embodiments of the serial receiver are provided along with methods for using the serial receiver.

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SERIAL CANCELLATION RECEIVER DESIGN FOR A CODED SIGNAL PROCESSING ENGINE

CROSS-REFERENCE TO RELATED APPLICATIONS

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This application makes reference to: U.S. Provisional Patent Application No. 60/354,093, entitled "A Parallel CSPE Based Receiver for Communication Signal Processing," filed February 5, 2002; U.S. Patent Application No. 10/178,541, entitled "Method and Apparatus to Compute the Geolocation of a Communication Device Using Orthogonal Projections," filed June 25, 2002; U.S. Provisional Patent Application No. 60/348,106, entitled "Serial Receiver Design for a Coded Signal Processing Engine," filed January 14, 2002; U.S. Provisional Patent Application No. 60/333,143, entitled "Method and Apparatus to Compute the Geolocation of a Communication Device Using Orthogonal Projection Methods," filed November 27, 2001; U.S. Provisional Patent Application No. 60/331,480, entitled "Construction of an Interference Matrix for a Coded Signal Processing Engine," filed November 16, 2001; U.S. Patent Application No. 09/988,218, entitled "Interference Cancellation In a Signal," filed November 19, 2001; U.S. Patent Application No. 09/988,219, entitled "A Method and Apparatus for Implementing Projections in Signal Processing Applications," filed November 19, 2001; U.S. Provisional Patent Application No. 60/326,199, entitled "Interference Cancellation in a Signal," filed October 2, 2001; U.S. Provisional Patent Application No. 60/325,215, entitled "An Apparatus for Implementing Projections in Signal Processing Applications," filed September 28, 2001; U.S. Provisional Patent Application No. 60/251,432, entitled "Architecture for Acquiring, Tracking and Demodulating Pseudorandom Coded Signals in the Presence of Interference," filed December 4, 2000; U.S. Patent Application No. 09/612,602, filed July 7, 2000; and to U.S. Patent Application No. 09/137,183, filed August 20, 1998. The entire disclosure and contents of these applications are hereby incorporated by reference.

30

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a serial cancellation architecture for a Coded Signal Processing Engine (CSPE) that is designed for interference cancellation in the reception of coded signals in a spread spectrum system. More specifically, the CSPE may be used in a cascading sense for successive acquisition, tracking and demodulation of pseudorandom (PN) coded signals in the presence of interference in a CDMA system.

Description of the Prior Art

In spread spectrum systems, whether it is a wireless communication system, a Global Positioning System (GPS) or a radar system, each transmitter may be assigned a unique code and in many instances each transmission from a transmitter is assigned a unique code. The code is nothing more than a sequence (often pseudorandom) of bits. Examples of codes include Gold codes (used in GPS – see Kaplan, Elliot D., Editor, *Understanding GPS: Principles and Applications*, Artech House 1996), Barker codes (used in radar – see Stimson, G.W., “*An Introduction to Airborne Radar*”, SciTech Publishing Inc., 1998) and Walsh codes (used in communications systems, such as cdmaOne – See IS-95). These codes may be used to spread the signal so that the resulting signal occupies some specified range of frequencies in the electromagnetic spectrum or the codes may be superimposed on another signal, which may also be a coded signal.

Assigning a unique code to each transmitter allows the receiver to distinguish between different transmitters. An example of a spread spectrum system that uses unique codes to distinguish between transmitters is a GPS system.

If a single transmitter has to broadcast different messages to different receivers, such as a base station in a wireless communication system broadcasting to multiple mobiles, one may use codes to distinguish between messages for each mobile. In this

scenario, each symbol for a particular user is encoded using the code assigned to that user. By coding in this manner, the receiver, by knowing its own code, may decipher the message intended for it from the superposition of message signals received.

5 In some communication systems, a symbol is assigned to a sequence of bits that comprise a message. For example, a long digital message may be grouped into sets of M bit sequences where each unique sequence is assigned a symbol. For example, if $M=6$, then each set of 6 bits may assume one of $2^6 = 64$ possibilities. Such a system would broadcast a waveform, called a symbol, which would represent a sequence of
10 transmitted bits. For example, the symbol α might denote the sequence 101101 and the symbol β might denote the sequence 110010. In the spread spectrum version of such a system, these symbols are codes. An example of such a communication system is the mobile to base station (forward/down) link of cdmaOne.

15 In some instances, such as in a coded radar system, each pulse is assigned a unique code so that the receiver is able to distinguish between different pulses by the codes.

Of course, all of these techniques may be combined to distinguish between
20 transmitters, messages, pulses and symbols in a single system. The key idea in all of these coded systems is that the receiver knows the code(s) of the message intended for it. By applying the code(s) correctly to the received signal, the receiver may extract the message for which it is intended. However, such receivers are more complex than receivers that distinguish between messages by time and/or frequency alone.
25 Complexity arises because the signal received is a linear combination of all the coded signals present in the spectrum of interest at any given time. The receiver must be able to extract the message intended for it from this linear combination of coded signals.

The following section presents the problem of interference in linear algebraic
30 terms and provides a method by which it may be cancelled.

Let \mathbf{H} be a matrix containing the spread signal from source number 1 and let θ_1 be the amplitude of the signal from this source. Let s_i be the spread signals for the remaining sources and let ϕ_i be the corresponding amplitudes. Suppose that the receiver is interested in source number 1. The signals from the other sources may be considered
 5 to be interference. The received signal is:

$$\mathbf{y} = \mathbf{H}\theta_1 + s_2\phi_2 + s_3\phi_3 + \dots + s_p\phi_p + \mathbf{n} \quad (1)$$

where \mathbf{n} is the additive noise term, and p is the number of sources in the CDMA system. Let the length of the vector \mathbf{y} be N , where N is the number of points in the integration window. The value of N is selected as part of the design process and is a trade-off
 10 between processing gain and complexity. N consecutive points of \mathbf{y} will be referred to as a segment.

In a wireless communication system, the columns of the matrix \mathbf{H} represent the various coded signals of interest and the elements of the vector θ are the amplitudes of
 15 the respective coded signals. For example, in the base station to mobile link of a cdmaOne system, the coded signals may include the various channels, *i.e.* pilot, paging, synchronization and traffic, of each base station's line-of-sight (LOS) or multipath fingers. In the mobile to base station link, the columns of the matrix \mathbf{H} may be the coded signals from a mobile LOS or one of its multipath signals.

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In a GPS system, the columns of the matrix \mathbf{H} are the coded signals of interest broadcast by the GPS satellites.

In an array application, the columns of the matrix are steering vectors, or
 25 equivalent array pattern vectors. These vectors characterize the relative phase recorded by each antenna in the array as a function of the location and motion dynamics of the source as well as the arrangement of the antennas in the array. In the model presented above, each column of the matrix \mathbf{H} signifies a steering vector corresponding to a particular source.

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Equation (1) may be written in the following matrix form:

$$\begin{aligned} \mathbf{y} &= \mathbf{H}\theta + \mathbf{S}\phi + \mathbf{n} \\ &= [\mathbf{HS}] \begin{bmatrix} \theta \\ \phi \end{bmatrix} + \mathbf{n} \end{aligned} \quad (2)$$

5 where

\mathbf{H} : spread signal matrix of the source of interest,

θ : amplitude vector of the source of interest,

$\mathbf{S} = [\mathbf{s}_2 \dots \mathbf{s}_p]$: spread signal matrix of all the other sources, *i.e.*, the interference, and

$\phi = [\phi_2 \dots \phi_p]$: interference amplitude vector.

10

Receivers that are currently in use correlate the measurement, \mathbf{y} , with a replica of \mathbf{H} to determine if \mathbf{H} is present in the measurement. If \mathbf{H} is detected, then the receiver knows the bit-stream transmitted by source number 1. Mathematically, this correlation operation is:

$$15 \quad \text{correlation function} = (\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{y} \quad (3)$$

where T is the transpose operation.

Substituting for \mathbf{y} from equation (2) illustrates the source of the power control requirement:

$$\begin{aligned} (\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{y} &= (\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T (\mathbf{H}\theta + \mathbf{S}\phi + \mathbf{n}) \\ &= (\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{H}\theta + (\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{S}\phi + (\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{n} \\ 20 \quad &= \theta + (\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{S}\phi + (\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{n} \end{aligned} \quad (4)$$

The middle term, $(\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{S}\phi$, in the above equation is the source of the near-far problem. If the codes are orthogonal, then this term reduces to zero, which implies that the receiver has to detect θ in the presence of noise, *i.e.* $(\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{n}$ only.

25 As the amplitudes of the other sources increase, the term $(\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T \mathbf{S}\phi$ contributes a significant amount to the correlation, which makes the detection of θ more difficult.

The normalized correlation function, $(\mathbf{H}^T \mathbf{H})^{-1} \mathbf{H}^T$, defined above, is in fact a matched filter and is based on an orthogonal projection of \mathbf{y} onto the space spanned by \mathbf{H} . When \mathbf{H} and \mathbf{S} are not orthogonal to each other, there is leakage of the components of \mathbf{S} into the orthogonal projection of \mathbf{y} onto \mathbf{H} . This leakage is geometrically illustrated in Figure 1. Note in Figure 1, that if \mathbf{S} were orthogonal to \mathbf{H} , the leakage component is zero as is evident from equation 4. The CSPE provides a solution to this interference leakage issue.

One way to mitigate this interference is to remove the interference in \mathbf{y} by means of a projection operation. Mathematically, a projection onto the space spanned by the columns of the matrix \mathbf{S} is given by:

$$\mathbf{P}_s = \mathbf{S}(\mathbf{S}^T \mathbf{S})^{-1} \mathbf{S}^T \quad (5)$$

A projection onto the space perpendicular to the space spanned by the columns of \mathbf{S} is obtained by subtracting the above projection \mathbf{P}_s from the identity matrix (a matrix with ones on the diagonal and zeros everywhere else). Mathematically, this projection is represented by:

$$\mathbf{P}_s^\perp = \mathbf{I} - \mathbf{P}_s = \mathbf{I} - \mathbf{S}(\mathbf{S}^T \mathbf{S})^{-1} \mathbf{S}^T \quad (6)$$

The projection matrix \mathbf{P}_s^\perp has the property that when it is applied to a signal of type $\mathbf{S}\phi$, *i.e.*, a signal that lies in the space spanned by the columns of \mathbf{S} , it completely removes $\mathbf{S}\phi$ no matter what the value of ϕ . Namely, the projection is magnitude independent. This interference cancellation operation is illustrated in equation 7:

$$\mathbf{P}_s^\perp (\mathbf{S}\phi) = (\mathbf{I} - \mathbf{S}(\mathbf{S}^T \mathbf{S})^{-1} \mathbf{S}^T) \mathbf{S}\phi = \mathbf{S}\phi - \mathbf{S}(\mathbf{S}^T \mathbf{S})^{-1} \mathbf{S}^T \mathbf{S}\phi = \mathbf{S}\phi - \mathbf{S}\phi = 0 \quad (7)$$

When applied to the measurement vector \mathbf{y} , it cancels the interference terms:

30

$$\mathbf{P}_s^\perp \mathbf{y} = \mathbf{P}_s^\perp (\mathbf{H}\boldsymbol{\theta} + \mathbf{S}\phi + \mathbf{n}) = \mathbf{P}_s^\perp \mathbf{H}\boldsymbol{\theta} + \mathbf{P}_s^\perp \mathbf{S}\phi + \mathbf{P}_s^\perp \mathbf{n} = \mathbf{P}_s^\perp \mathbf{H}\boldsymbol{\theta} + \mathbf{P}_s^\perp \mathbf{n} \quad (8)$$

Detection of the signal interest may then proceed with the processed measurement vector $\mathbf{P}_s^\perp \mathbf{y}$ with the interference signal(s) \mathbf{S} removed.

5

This method of projections and interference cancellation may be incorporated as an improvement to the baseline receiver for spread spectrum signal reception.

The present invention is a receiver with improved correlation properties that makes use of the principle of orthogonal projections as described in the patent applications identified and incorporated by reference above.

10

SUMMARY OF THE INVENTION

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It is therefore an object of the present invention to provide a novel serial cancellation receiver architecture for the Coded Signal Processing Engine (CSPE).

It is a further object to provide an apparatus by which PN coded signals may be successively acquired, tracked, demodulated and cancelled in a cascading sense.

20

It is yet another object to provide an apparatus by which signals buried by interference may be successively detected through repeated serial cancellations.

In all of the above embodiments, it is an object to provide a method for interference cancellation in the reception of PN coded signals.

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According to a first broad aspect of the present invention, there is provided an architecture for implementing a forward link serial cancellation CSPE receiver for cdmaOne.

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According to second broad aspect of the invention, there is provided an architecture for implementing a forward link serial cancellation CSPE receiver for cdma2000.

5 In a preferred embodiment, a serial receiver for a wireless communication system is provided, the communication system comprising: a means for receiving a signal y having data parameters; a control processor; the control processor for receiving the signal y and the data parameters; at least two fingers, the control processor for determining which of the data parameters are sent to respective fingers, wherein one
10 finger is a search finger and at least one finger is a tracking finger; and wherein the tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), the CSPE for interference cancellation in the reception of the signal y .

In another embodiment, a serial receiver for a wireless communication system is
15 provided, the communication system comprising: a means for receiving a signal y having data parameters; a control processor; the control processor for receiving the signal y and the data parameters; at least two fingers, the control processor for determining which data parameters are sent to respective fingers, wherein one finger is a search finger and at least one finger is a tracking finger; wherein the tracking finger
20 comprises a correlator and a Coded Signal Processing Engine (CSPE), the CSPE for interference cancellation in the reception of the measured signal; wherein the CSPE comprises: an apparatus for generating a projection from a received signal (y), the signal comprising s_i , a signal of the source of interest; $s_1, s_2, s_3, \dots, s_p$ signals of other interfering sources; and noise (n); the apparatus comprising: means for determining a
25 basis vector U ; means for storing elements of the basis vector U ; means for determining y_{perp} where: $y_{\text{perp}} = y - U(U^T U)^{-1} U^T y$; and wherein the search finger receives an input from the control processor, the input being selected from the group consisting of: $y^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$, a product of projection operators used to remove the k interference signals.

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In another embodiment, a serial receiver for a wireless communication system is provided, the communication system comprising: a means for receiving a signal \mathbf{y} having data parameters; a control processor; the control processor for receiving the signal \mathbf{y} and the data parameters; at least two fingers, the control processor for

5 determining which of the data parameters are sent to respective fingers, wherein one finger is a search finger and at least one finger is a tracking finger; wherein the tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), the CSPE for interference cancellation in the reception of the measured signal; wherein the CSPE comprises: an apparatus for generating a projection from a received signal (\mathbf{y}), the signal

10 comprising \mathbf{s}_i , a spread signal matrix of the source of interest; $\mathbf{s}_1, \mathbf{s}_2, \mathbf{s}_3, \dots, \mathbf{s}_p$, signals of other interfering sources; and noise (\mathbf{n}); the apparatus comprising: (A) means for assigning \mathbf{s}_1 as a first basis vector \mathbf{u}_1 ; (B) means for determining σ_i , where $\mathbf{u}_i^T \mathbf{u}_i = \sigma_i$; (C) means for storing \mathbf{u}_i ; (D) means for computing inner products of the \mathbf{s}_{i+1} and the \mathbf{u}_1 through \mathbf{u}_i vectors; (E) means for multiplying the inner products with a

15 respective scalar $1/\sigma_i$ and thereby creating a first intermediate product; (F) means for scaling each respective basis vector \mathbf{u}_i by multiplying each respective first intermediate product with each respective basis vector \mathbf{u}_i ; (G) means for serially subtracting the intermediate product from \mathbf{s}_{i+1} ; (H) means for utilizing the result from step G and subtracting the next incoming value of $\mathbf{u}_i \frac{1}{\sigma_i} \mathbf{u}_i^T \mathbf{s}_{i+1}$ until all the values are processed; (I)

20 means for obtaining the next basis vector \mathbf{u}_{i+1} from step H; (J) means for comparing \mathbf{u}_{i+1} to a predetermined value and if equal to or less than the value, going to step O; (K) means for storing \mathbf{u}_{i+1} ; (L) means for determining an inner product of $\mathbf{u}_{i+1}^T \mathbf{u}_{i+1}$; (M) means for determining the reciprocal of step K which is $1/\sigma_{i+1}$; (N) means for storing $1/\sigma_{i+1}$; (O) means for incrementing i ; (P) means for conducting steps D through O until

25 $i=p$, where p is the total number of the sources of interest; (Q) and means for determining \mathbf{y}_{perp} where: $\mathbf{y}_{\text{perp}} = \mathbf{y} - \mathbf{U}(\mathbf{U}^T \mathbf{U})^{-1} \mathbf{U}^T \mathbf{y}$; and wherein the search finger receives an input from the control processor, the input being selected from the group

consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$, a product of projection operators used to remove the k interference signals.

In another embodiment, a serial receiver for a wireless communication system is provided, the communication system comprising: a means for receiving a signal \mathbf{y} having data parameters; a control processor; the control processor for receiving the signal \mathbf{y} and the data parameters; at least two fingers, the control processor for determining which of the data parameters are sent to respective fingers, wherein one finger is a search finger and at least one finger is a tracking finger; wherein the tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), the CSPE for interference cancellation in the reception of the measured signal; wherein the CSPE comprises: an apparatus for generating a projection from a received signal (\mathbf{y}), the signal comprising \mathbf{s}_i , a signal of the source of interest; $\mathbf{s}_1, \mathbf{s}_2, \mathbf{s}_3, \dots, \mathbf{s}_p$, signals of other sources; and noise (\mathbf{n}); the apparatus comprising: means for determining a basis vector \mathbf{U} ; means for storing elements of the basis vector \mathbf{U} ; means for determining \mathbf{y}_{perp} where: $\mathbf{y}_{\text{perp}} = \mathbf{y} - \mathbf{U}(\mathbf{U}^T \mathbf{U})^{-1} \mathbf{U}^T \mathbf{y}$; and wherein the search finger receives an input from the control processor, the input being selected from the group consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$, a product of a projection operator used to remove the k interference signals.

20

In another embodiment, a serial receiver for a wireless communication system is provided, the communication system comprising: a means for receiving a signal \mathbf{y} having data parameters; a control processor; the control processor for receiving the signal \mathbf{y} and the data parameters; at least two fingers, the control processor for determining which of the data parameters are sent to respective fingers, wherein one finger is a search finger and at least one finger is a tracking finger; wherein the tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), the CSPE for interference cancellation in the reception of the signal \mathbf{y} ; and wherein the tracking finger further comprises a tracking loop and a means for signal demodulation.

25

In another embodiment, a modified Hadamard transform module is provided, the module comprising: an input signal y ; means for splitting the input signal into a plurality of input channels; a plurality of relative amplitude generation channels, one associated with each of the input channels, wherein at least one of the relative amplitude generation channels comprises a respective Walsh code which is multiplied by a projection matrix P_s^\perp and the signal y to generate a respective intermediate channel signal; and a summer for summing the respective intermediate channel signal over a Walsh symbol to generate the respective channel's amplitude.

10

In another embodiment, a method for generating an S matrix is provided, the method comprising the steps of:

- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
- 15 B. Determining which input signals will be utilized in the generation of matrix S ;
- C. Multiplying each selected input signal with a projection matrix P_s^\perp to generate a column of matrix S ; and
- D. Storing each respective column to form matrix S .

20

In another embodiment, an apparatus for generating an S matrix is provided, the apparatus comprising: a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals; a means for determining which input signals will be utilized in the generation of matrix S ; a means for multiplying each selected input signal with a projection matrix P_s^\perp to generate a column of matrix S ; and means for storing each respective column to form matrix S .

25

In another embodiment, a method for generating an S matrix is provided, the method comprising the steps of:

- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
- B. Determining which input signals will be utilized in the generation of matrix **S**;
- 5 C. Multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal;
- D. Utilizing relative amplitude information associated with the selected input signals to determine the sign of the selected input signal;
- E. Multiplying the intermediate signal with its associated sign to generate a
10 column of matrix **S**; and
- F. Storing each respective column to form matrix **S**.

In another embodiment, an apparatus for generating an **S** matrix is provided, the apparatus comprising: a means for receiving a plurality of input signals W_1 through W_n ,
15 where n represents the number of input signals; a means for determining which input signals will be utilized in the generation of matrix **S**; a first means for multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal; a means for utilizing relative amplitude information associated with the input signals to determine the sign of the input signal; a second means for multiplying the intermediate
20 signal with its associated sign to generate a column of matrix **S**; and means for storing each respective column to form matrix **S**.

In another embodiment, a method for generating an **S** matrix is provided, the method comprising the steps of:

- 25 A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
- B. Determining which input signals will be utilized in the generation of matrix **S**;
- C. Multiplying each selected input signal with a projection matrix P_s^\perp to
30 generate an intermediate signal;

- D. Determining relative amplitude associated with the selected input signals;
- E. Multiplying the intermediate signal with its associated relative amplitude to generate a column of matrix **S**; and
- 5 F. Storing each respective column to form matrix **S**.

In another embodiment, an apparatus for generating an **S** matrix is provided, the apparatus comprising: a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals; a means for determining which input
10 signals will be utilized in the generation of matrix **S**; a first means for multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal; a means for determining relative amplitude associated with the respective input signal; a second means for multiplying the intermediate signal with its associated relative amplitude to generate a column of matrix **S**; and means for storing each respective
15 column to form matrix **S**.

In another embodiment, a method for generating an **S** matrix is provided, the method comprising the steps of:

- 20 A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
- B. Determining which input signals will be utilized in the generation of matrix **S**;
- C. Multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal;
- 25 D. Determining relative amplitude associated with the selected input signals;
- E. Multiplying the intermediate signal with its associated relative amplitude to generate an intermediate column;
- F. Summing all intermediate columns to generate a column of matrix **S**; and
- G. Storing each respective column of matrix **S** to form matrix **S**.

30

In another embodiment, an apparatus for generating an **S** matrix is provided, the apparatus comprising: a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals; a means for determining which input signals will be utilized in the generation of matrix **S**; a first means for multiplying each
5 selected input signal with a projection matrix P_s^\perp to generate a column of matrix **S** and an intermediate signal; means for determining relative amplitude associated with the selected input signals; second means for multiplying the intermediate signal with its associated relative amplitude to generate an intermediate column; means for summing all intermediate columns to generate a column of matrix **S**; and means for storing each
10 respective column of matrix **S** to form matrix **S**.

In another embodiment, a modified Hadamard transform module is provided, the module comprising: an input signal y , the signal having an in-phase component (y_i) and a quadrature component (y_q); means for splitting the in-phase component (y_i) into a first
15 plurality of input channels; a first plurality of relative amplitude generation channels, one associated with each of the first input channels, wherein at least one of the relative amplitude generation channels comprises a respective Walsh code which is multiplied by a projection matrix $P_{s_i}^\perp$ and the in-phase component (y_i) to generate a respective first intermediate channel signal; a first summer for summing the respective first
20 intermediate channel signal over a Walsh symbol to generate the respective channel's amplitude; means for splitting the quadrature component (y_q) into a second plurality of input channels; a second plurality of relative amplitude generation channels, one associated with each of the second input channels, wherein at least one of the relative amplitude generation channels comprises a respective Walsh code which is multiplied
25 by a projection matrix $P_{s_q}^\perp$ and the quadrature component (y_q) to generate a respective second intermediate channel signal; and a second summer for summing the respective second intermediate channel signal over a Walsh symbol to generate the respective channel's amplitude.

In another embodiment, a method for generating an **S** matrix is provided, the **S** matrix having an in-phase and a quadrature component, the method comprising the steps of:

- 5 A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);
- B. Determining which in-phase components of the input signals will be utilized in the generation of matrix **S_I**;
- 10 C. Multiplying each in-phase component of the selected input signal with a projection matrix $P_{s_I}^\perp$ to generate a column of matrix **S_I**;
- D. Storing each respective column to form matrix **S_I**;
- E. Determining which quadrature components of the input signals will be utilized in the generation of matrix **S_Q**;
- 15 F. Multiplying each quadrature component of the selected input signal with a projection matrix $P_{s_Q}^\perp$ to generate a column of matrix **S_Q**; and
- G. Storing each respective column to form matrix **S_Q**.

In another embodiment, an apparatus for generating an **S** matrix is provided, the **S** matrix having an in-phase and a quadrature component, the apparatus comprising: a
 20 means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q); a means for determining which in-phase components of the input signals will be utilized in the generation of matrix **S_I**; a first means for multiplying each in-phase component of the selected input signal with a projection
 25 matrix $P_{s_I}^\perp$ to generate a column of matrix **S_I**; means for storing each respective column to form matrix **S_I**; a means for determining which quadrature components of the input signals will be utilized in the generation of matrix **S_Q**; a second means for multiplying each quadrature component of the selected input signal with a projection matrix $P_{s_Q}^\perp$ to

generate a column of matrix S_Q ; and means for storing each respective column to form matrix S_Q .

In another embodiment, a method for generating an S matrix is provided, the S matrix having an in-phase and a quadrature component, the method comprising the steps of:

- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);
- 10 B. Determining which in-phase components of the input signals will be utilized in the generation of matrix S_I ;
- C. Multiplying each in-phase component of the selected input signal with a projection matrix $P_{s_i}^\perp$ to generate an in-phase intermediate signal;
- D. Utilizing relative amplitude information associated with the in-phase component of the selected input signals to determine the sign of the selected in-phase component of the input signal;
- 15 E. Multiplying the in-phase intermediate signal with its associated sign to generate a column of matrix S_I ;
- F. Storing each respective column to form matrix S_I ;
- 20 G. Determining which quadrature components of the input signals will be utilized in the generation of matrix S_Q ;
- H. Multiplying each quadrature component of the selected input signal with a projection matrix $P_{s_q}^\perp$ to generate a quadrature intermediate signal;
- I. Utilizing relative amplitude information associated with the quadrature component of the selected input signals to determine the sign of the selected quadrature component of the input signal;
- 25 J. Multiplying the quadrature intermediate signal with its associated sign to generate a column of matrix S_Q ; and
- K. Storing each respective column to form matrix S_Q .

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In another embodiment, an apparatus for generating an **S** matrix is provided, the **S** matrix having an in-phase and a quadrature component, the apparatus comprising: a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q); a means for determining which in-phase components of the input signals will be utilized in the generation of matrix **S_I** and **S_Q**; a first means for multiplying each in-phase component of the selected input signal with a projection matrix $P_{s_I}^\perp$ to generate an in-phase intermediate signal; a means for utilizing relative amplitude information associated with the in-phase component of the input signals to determine the sign of the in-phase component of the input signal; a second means for multiplying the in-phase intermediate signal with its associated sign to generate a column of matrix **S_I**; means for storing each respective column to form matrix **S_I**; a third means for multiplying each quadrature component of the selected input signal with a projection matrix $P_{s_Q}^\perp$ to generate a quadrature intermediate signal; a means for utilizing relative amplitude information associated with the quadrature component of the input signals to determine the sign of the quadrature component of the input signal; a fourth means for multiplying the quadrature intermediate signal with its associated sign to generate a column of matrix **S_Q**; and means for storing each respective column to form matrix **S_Q**.

20

In another embodiment, a method for generating an **S** matrix is provided, the **S** matrix having an in-phase and a quadrature component, the method comprising the steps of:

- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);
- B. Determining which input signals will be utilized in the generation of matrix **S_I**;
- C. Multiplying each in-phase component of the selected input signal with a projection matrix $P_{s_I}^\perp$ to generate an in-phase intermediate signal;

30

- D. Determining relative amplitude associated with the in-phase component of the selected input signals;
- E. Multiplying the in-phase intermediate signal with its associated relative amplitude to generate a column of matrix \mathbf{S}_I ;
- 5 F. Summing each column of matrix \mathbf{S}_I to generate a composite column;
- G. Storing the composite column to form matrix \mathbf{S}_I ;
- H. Determining which input signals will be utilized in the generation of matrix \mathbf{S}_Q ;
- I. Multiplying each quadrature component of the selected input signal with a
10 projection matrix $P_{s_q}^\perp$ to generate a quadrature intermediate signal;
- J. Determining relative amplitude associated with the quadrature component of the selected input signals;
- K. Multiplying the quadrature intermediate signal with its associated relative amplitude to generate a column of matrix \mathbf{S}_Q ;
- 15 L. Summing each column of matrix \mathbf{S}_Q to generate a composite column; and
- M. Storing the composite column to form matrix \mathbf{S}_Q .

In another embodiment, an apparatus for generating an \mathbf{S} matrix is provided, the \mathbf{S} matrix having an in-phase and a quadrature component, the apparatus comprising: a
20 means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q); a means for determining which input signals will be utilized in the generation of matrix \mathbf{S}_I and \mathbf{S}_Q ; a first means for multiplying each in-phase component of the selected input signal with a projection matrix $P_{s_I}^\perp$ to generate
25 an in-phase intermediate signal; a means for determining relative amplitude associated with the in-phase component of the respective input signal; a second means for multiplying the in-phase intermediate signal with its associated relative amplitude to generate a column of matrix \mathbf{S}_I ; first means for summing each column of matrix \mathbf{S}_I to generate a first composite column; first means for storing the first composite column to
30 form matrix \mathbf{S}_I ; a third means for multiplying each quadrature component of the selected

input signal with a projection matrix $P_{s_Q}^\perp$ to generate a quadrature intermediate signal; a means for determining relative amplitude associated with the quadrature component of the respective input signal; a fourth means for multiplying the quadrature intermediate signal with its associated relative amplitude to generate a column of matrix S_Q ; means
5 for summing each column of matrix S_Q to generate a second composite column; and means for storing the second composite column to form matrix S_Q .

In another embodiment, a method for generating an S matrix is provided, the method comprising the steps of:

- 10 A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
- B. Determining which input signals will be utilized in the generation of matrix S ;
- C. Multiplying each of the selected input signals with a projection matrix P_s^\perp to
15 generate an intermediate signal;
- D. Determining relative amplitude associated with the component of the selected input signals;
- E. Multiplying the intermediate signal with its associated relative amplitude to generate a column of matrix S ;
- 20 F. Summing each column of matrix S to generate a composite column; and
- G. Storing the composite column to form matrix S .

Other objects and features of the present invention will be apparent from the following detailed description of the preferred embodiment.

25

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in conjunction with the accompanying drawings, in which:

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Figure 1 is a depiction of leakage due to orthogonal projections of non-orthogonal signal spaces in prior art signal-processing;

5 Figure 2 is a block diagram depicting a generalized architecture of a serial receiver constructed in accordance with a preferred embodiment of the present invention;

10 Figure 3 is a depiction of how a projection operator may be applied to a reference signal when symbol boundaries of a signal being cancelled are not aligned with the reference symbol boundaries;

Figure 4 is a depiction of misalignment of symbol boundaries and the inherent causality in cancellation associated therewith;

15 Figure 5 is a block diagram depicting an architecture for a forward link receiver constructed in accordance with the teachings of the present invention and utilized in cdmaOne and/or cdma2000 systems;

20 Figure 6 is a block diagram depicting a searcher finger of the receiver illustrated in Figure 5 and utilized in a cdmaOne system;

Figure 7 is a block diagram depicting a processing finger of the receiver illustrated in Figure 5 and utilized in a cdmaOne system;

25 Figure 8 is a block diagram depicting a modified Hadamard transform module that may be utilized in conjunction with the present teachings of the invention in a cdmaOne system;

30 Figure 9 is a block diagram depicting a module for the generation of an interference matrix S , using 'no information' of sign or relative amplitude, which may

be utilized in conjunction with the teachings of the present invention in a cdmaOne system and/or cdma2000 system;

5 Figure 10 is a block diagram depicting a module for the generation of an interference matrix S , using 'sign information', that may be utilized in conjunction with the teachings of the present invention in a cdmaOne system and/or cdma2000 system;

10 Figure 11 is a block diagram depicting a module for the generation of an interference matrix S , using 'relative amplitude (composite)' information, which may be utilized in conjunction with the teachings of the present invention in a cdmaOne system and/or cdma2000 system;

15 Figures 12A and B illustrate block diagrams which depict two examples of modules combining methods for a generation of an interference matrix S that may be utilized in conjunction with the teachings of the present invention in a cdmaOne system;

Figure 13 is a block diagram depicting a searcher finger for the receiver illustrated in Figure 5 and utilized in a cdma2000 system;

20 Figure 14 is a block diagram depicting a processing finger for the receiver illustrated in Figure 5 and utilized in a cmda2000 system;

25 Figure 15 is a block diagram depicting an amplitude estimator module for the receiver illustrated in Figure 5 and utilized in a cdma2000 system;

Figures 16A and 16B are block diagrams depicting in phase and quadrature modules for the generation of a 'no information' interference matrix S that may be utilized in conjunction with the teachings of the present invention in a cdma2000 system;

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Figures 17A and 17B are block diagrams depicting in phase and quadrature modules for the generation of a ‘sign information’ interference matrix **S** that may be utilized in conjunction with the teachings of the present invention in a cdma2000 system; and

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Figures 18A and 18B are block diagrams depicting in phase and quadrature modules for the generation of ‘relative amplitude (composite)’ interference matrix **S** that may be utilized in conjunction with the teachings of the present invention in a cdma2000 system.

10

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

It is advantageous to define several terms before describing the invention. It should be appreciated that the following definitions are used throughout this application.

15

Where the definition of terms departs from the commonly used meaning of the term, applicant intends to utilize the definitions provided below, unless specifically indicated.

Definitions

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For the purposes of the present invention, the term “cross-channel interference” refers to the type of interference that results from one source’s signals bleeding into the acquisition and tracking channels of another source.

25

For the purposes of the present invention, the term “co-channel interference” refers to the type of interference that occurs when one or more signals, *e.g.*, a line-of-sight signal; interferes with the ability to acquire a second, third or other multipath signal from the same source.

30

For the purposes of the present invention, the term “finger” refers to either an LOS or multipath copy of a signal from any source. It may consist of multiple channels.

For example, an IS-95 multipath finger may consist of the pilot, paging, synchronization and a number of traffic channels.

5 For the purposes of the present invention, the term “multipath finger” refers specifically to either an LOS or multipath signal from a single source. It may consist of multiple channels. For example, an IS-95 multipath finger may consist of the pilot, paging, synchronization and a number of traffic channels.

10 For the purposes of the present invention, the term “processing finger” refers to a signal-processing element in a receiver that tracks a single multipath finger and processes a single channel contained in a multipath finger. For example, in an IS-95 mobile receiver, each processing finger tracks a single multipath finger of a channel.

15 For the purposes of the present invention, the term “analog” refers to any measurable quantity that is continuous in nature.

20 For the purposes of the present invention, the term “base station” refers to a transmitter and/or receiver that is capable of communicating with multiple mobile units in a wireless environment.

For the purposes of the present invention, the term “baseline receiver” refers to a conventional CDMA receiver against which a receiver of the present invention may be compared.

25 For the purposes of the present invention, the term “baseline finger processor” refers to a processing finger in a baseline receiver that tracks a finger.

30 For the purposes of the present invention, the term “bit” refers to the conventional meaning of “bit,” *i.e.*, a fundamental unit of information having one of two possible values; a binary 1 or 0.

For the purposes of the present invention, the term “chip” refers to a non-information bearing unit that is smaller than a bit, the fundamental information bearing unit. Use of spreading codes produce fixed length sequences of chips that constitute bit(s).

5

For the purposes of the present invention the term “code” refers to a specified sequence of numbers that is applied to a message and is known by the intended recipient of the message.

10

For the purposes of the present invention the term “Code-Division Multiple Access (CDMA)” refers to a method for multiple access in which all users share the same spectrum but are distinguishable from each other by a unique code.

For the purposes of the present invention, the term “code offset” refers to a location within a code. For example, base stations in certain wireless environments distinguish between each other by their location within a code, often a pseudorandom sequence.

For the purposes of the present invention, the term “correlation” refers to the inner product between two signals, typically scaled by the length of the signals or by another normalization factor. Correlation provides a measure of how alike two signals are.

For the purposes of the present invention, the term “digital” refers to the conventional meaning of the term digital, *i.e.*, relating to a measurable quantity that is discrete in nature.

For the purposes of the present invention, the term “Doppler” refers to the conventional meaning of the term Doppler, *i.e.*, a shift in frequency that occurs due to movement of a receiver, transmitter and/or background.

30

For the purposes of the present invention, the term “Global Positioning System (GPS)” refers to the conventional meaning of this term, *i.e.*, a satellite-based system for position location.

5 For the purposes of the present invention, the term “in-phase” refers to the component of a signal that is aligned in phase with a particular signal, such as a reference signal.

10 For the purposes of the present invention, the term “quadrature” refers to the component of a signal that is 90° out of phase with a particular signal, such as a reference signal.

15 For the purposes of the present invention, the term “interference” refers to the conventional meaning of the term interference, *i.e.*, a signal that is not of interest but that interferes with the ability to detect the signal of interest. Generally, interference is structured noise that is created by other processes that are attempting to do the same thing as the signal of interest, *e.g.*, other base stations communicating with mobiles, or multipath versions of the signal of interest.

20 For the purposes of the present invention, the term “linear combination” refers to the combining of multiple signals or mathematical quantities in an additive way with nonzero scaling of the individual signals.

25 For the purposes of the present invention, the term “matched filter” refers to a filter that is designed to facilitate the detection of a known signal by effectively correlating the received signal with an uncorrupted replica of the known signal.

30 For the purposes of the present invention, the term “noise” refers to the conventional meaning of noise with respect to the transmission and reception of signals, *i.e.*, a random disturbance that limits the ability to detect a signal of interest. Specifically, it refers to processes that are attempting to do something different than the

signal of interest. Additive noise adds linearly with the power of the signal of interest. Examples of noise in cellular systems may include automobile ignitions, power lines and microwave communication links.

5 For the purpose of the present invention, the term “matrix inverse” refers to the inverse of a square matrix \mathbf{S} , denoted by \mathbf{S}^{-1} , that is defined as that matrix which when multiplied by the original matrix equals the identity matrix, \mathbf{I} , *i.e.*, a matrix which is all zero save for a diagonal of all ones.

10 For the purposes of the present invention, the term “mobile” refers to a mobile phone which functions as a transmitter or receiver and communicates with base stations.

For the purposes of the present invention, the term “modulation” refers to imparting information on another signal, such as a sinusoidal signal or a pseudorandom
15 coded signal. Typically, this is accomplished by manipulating signal parameters, such as phase, amplitude, frequency or some combination of these quantities.

For the purposes of the present invention, the term “multipath” refers to copies of a signal that travel different paths to the receiver.

20

For the purposes of the present invention, the term “normalization” refers to a scaling relative to another quantity.

For the purposes of the present invention, two nonzero vectors, \mathbf{e}_1 and \mathbf{e}_2 are said
25 to be “orthogonal” if their inner product (defined as $\mathbf{e}_1^T \mathbf{e}_2$, where T refers to the transpose operator) is identically zero. Geometrically, this refers to vectors that are perpendicular to each other.

For the purposes of the present invention, the term “pseudorandom number
30 (PN)” sequences refer to sequences that are often used in spread spectrum applications

as codes to distinguish between users while spreading the signal in the frequency domain.

For the purposes of the present invention, the term “processing gain” refers to the ratio of signal to noise ratio (SNR) of the processed signal to the SNR of the unprocessed signal.

For the purposes of the present invention, the term “projection”, with respect to any two vectors \mathbf{x} and \mathbf{y} , refers to the projection of the vector \mathbf{x} onto \mathbf{y} in the direction of \mathbf{y} with a length equal to that of the component of \mathbf{x} , which lies in the \mathbf{y} direction.

For the purposes of the present invention, the term “quasi-orthogonal functions (QOF)” refers to a set of orthogonal functions used in cdma2000. QOFs are orthogonal within a set, but between different QOF sets and Walsh codes there exists non-zero correlation between at least one pair of codes from these different sets.

For the purposes of the present invention, the term “rake receiver” refers to a method for combining multipath signals in order to increase the processing gain.

For the purposes of the present invention, the term “signal to noise ratio (SNR)” refers to the conventional meaning of signal to noise ratio, *i.e.*, the ratio of the signal to noise (and interference).

For the purposes of the present invention, the term “spread spectrum” refers to techniques that use spreading codes to increase the bandwidth of a signal to more effectively use bandwidth while being resistant to frequency selective fading.

For the purposes of the present invention, the term “spreading code” refers to pseudorandom number sequences that are used to increase the width of the signal in frequency space in spread spectrum systems. Examples of spreading codes include: Gold, Barker, Walsh codes, *etc.*

For the purposes of the present invention, the term “steering vector” refers to a vector that contains the phase history of a signal that is used in order to focus the signal of interest.

5

For the purposes of the present invention, the term “symbol” refers to the fundamental information-bearing unit transmitted over a channel in a modulation scheme. A symbol may be composed of one or more bits that may be recovered through demodulation

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For the purposes of the present invention, the term “transpose” refers to a mathematical operation in which a matrix is formed by interchanging rows and columns of another matrix. For example, the first row becomes the first column; the second row becomes the second column, and so on.

15

Description

The serial cancellation CSPE receiver incorporates the coded signal-processing engine (CSPE) into a spread spectrum receiver architecture in which interference cancellation is performed in a serial manner. Specifically, interference cancellation operations of single fingers, *e.g.*, single LOS or multipath from a transmission source, on the measured data are performed in a serial, or cascading, manner, typically from highest to lowest power signals. Each processing finger may operate on the measured data y or on processed data in which one or more interference signals have been cancelled. One benefit of the serial approach is that a serial receiver processing-finger may acquire, track and demodulate a signal that is buried beneath the interference floor. A master control module controls data flow and control signals for all processing fingers. Depending on the power of the signals acquired, the CSPE may or may not cancel the interference of the previous signal(s).

30

The serial architecture 200 is presented in Figure 2 in a generalized form with an arbitrary number of processing fingers 210, 212, 214. For clarity, only three processing fingers are illustrated. Particular embodiments, later described, will provide cdmaOne and cdma2000 specific elements of the present invention. Figure 2 depicts a serial receiver 200 and an arbitrary finger processor 260 containing finger 212 and illustrating the data flow therein. Signal 202 may either be processed at an intermediate frequency (IF) or at base-band (BB) frequency. The connections depicted in the subsequent figures may either be for a single IF signal or I (in-phase) and Q (quadrature) base-band signals.

10

A description of each element of Figure 2 is contained in the following subsections.

Control

Control block 206 controls data flow for all processing fingers 210, 212, 214 in receiver 200, *i.e.*, it determines which data stream, time offsets, projection operators and other parameters are sent to each processing finger 210, 212, 214. Moreover, it maintains a master time or an equivalent method of representing time of arrival that is used by all the processing fingers for the determination of code offsets in time. Controller 206 may be modified as desired to achieve particular network requirements. Note that it is to be understood that various changes and modifications may be made to controller 206 without departing from the teachings of the present invention. Such changes and modifications are to be understood as included within the scope of the present invention. For example, due to memory and other computational reasons it may be necessary to pass the interference matrix \mathbf{S} to a module rather than the projection matrix \mathbf{P}_S^\perp .

In a preferred embodiment, the inputs for controller 206 are illustrated as items 202 and 204 and may include, but are not limited to: $y^{(j)}$ – data stream containing the transmitted signals where the j index specifies the number of interference signals that

30

have been removed; t_k – time offset for the signal, where k is the signal index; $P_{s_n^{(k)}}^\perp$ – projection operator, where the n index denotes the signal number while the k index specifies the number of interference signals that have been removed; P – estimate of the power of the tracked signals to determine which signals should be cancelled and in which order the signals should be cancelled; and *Info* – an optional parameter that may either specify relative signal amplitude of the signals or polarity of the bits transmitted. This information is specifically used for cancellation purposes. The minimum input parameters for cancellation purposes include: $y^{(j)}$, t_k , and $P_{s_n^{(k)}}^\perp$.

The outputs for controller 206 are illustrated as data elements 208, 210, 212, 214, and 216. Each of these data elements may contain: $y^{(k)}$ – a data stream in which k interference signals have been removed; $\prod_{i,j} P_{s_i^{(j)}}^\perp$ – a product of the projection operators that is used to remove the k interference signals; and/or t_k – time offset for the k th interference signal.

15

Searcher Finger

Searcher finger block 220 acquires a signal in the received data 208. Inputs for searcher finger block 220, include, but are not limited to: $y^{(j)}$ – a data stream in which j interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$ – a product of the projection operators, which is used to remove the k interference signals. Searcher finger block 220 provides time offset and relative power information to finger processor 260. The time offset is a coarse approximation, the accuracy of which is further refined in the tracking loop or code offset estimation of finger processor 260. Searcher finger block 220 may operate on either the unprocessed segment of data or on a processed segment of data, which has been operated on by a projection operator in a processing finger's CSPE block in order to remove an interference signal(s).

25

Depending on the constraints of the system, the searcher algorithm may take many forms. A standard CDMA searcher continually searches the unprocessed segment y 202 for new signals to be assigned to processing fingers 210, 212, 214. Embodiments of the present invention have the capability to search within unprocessed data and the processed data, *e.g.*, $y^{(1)}$, $y^{(2)}$, ..., $y^{(n-1)}$. For example, the searcher algorithm may focus its processing time on the y 202 with the greatest number of signals removed to facilitate the acquisition of signals buried by the interference, it could search each y alternatively for a short period of time or have additional searchers or correlators search $y^{(1)}$, $y^{(2)}$, ..., $y^{(n-1)}$. The former has difficulties when the relative powers of the signals are changing and fingers are being reassigned because of the dependencies of cancellation ordering in the serial cancellation process. The latter may unnecessarily process y 's with few or no signals cancelled, thereby decreasing the probability of acquiring additional signals since they may be buried beneath the interference floor of stronger signals. The addition of new searchers or correlators may be costly to implement. The complexity of the searcher algorithm is dependent on the parameters of receiver architecture.

The use of any prior art searcher algorithm is considered within the scope of the present invention. As may be seen, the outputs from searcher finger block 220 are preferably, t_m – time offset for the (m)th signal acquired by the searcher; and an estimate of signal power that is used to determine the order of the serial cancellation and to determine whether signal cancellation is required for the acquisition of particular signals. The output is illustrated by element 222. Outputs 222 may be utilized to facilitate the acquisition of signals buried by the interference or may search each $y^{(j)}$ alternatively for a short period of time, for simplicity, and may be provided to controller 206 as input 204 for these purposes.

Baseline Finger Processor

Baseline finger processor 230 tracks a signal in the received data $y^{(k)}$ in 212. It provides time offset information t_{k+1} and an estimate of the tracked signal (reference

signal) 232 to subsequent blocks in the processing finger for correlator 240 and for the construction of interference matrices 250. The inputs for baseline finger processor 230 are illustrated by element 212 and include: $y^{(k)}$ – a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$ – a product of the projection operators which
 5 is used to remove the k interference signals.

If the data has been operated on by a projection operator in another processing finger's CSPE block 250, in order to remove an interference signal(s), then it will be necessary to use the projection operator(s) in the creation of a reference signal for
 10 correlation purposes. This is illustrated as one of the inputs in 232.

As may be seen from Figure 2, the outputs from baseline finger processor 230 are: $\prod_{i,j} P_{s_i^{(j)}}^\perp s_n$ – a product of the projection operators, used to remove the k interference signals, and a reference signal of the signal tracked in the baseline receiver where n
 15 specifies the signal index; and t_{k+1} – time offset for the $(k+1)$ th signal tracked in the baseline receiver. These outputs are represented by element 232. As may be seen, output 232 is provided to both correlator 240 and CSPE 250.

Correlator block 240 (shown in Figure 2) calculates a power estimate P in 244
 20 that is used by control block 206 to order the signals for serial cancellation. Namely, it determines whether a cancellation is necessary in each processing finger and in which order. Additionally, the parameter *Info* is provided that supplies either information on bits transmitted, relative power information or no information to control block 206 depending on the receiver architecture. Information on bits transmitted or relative
 25 power is necessary for certain cancellation methods where there is bit boundary misalignment and where cancellation is performed on segments longer than one Walsh symbol as disclosed in U.S. Provisional Patent Application No. 60/331,480, entitled "Construction of an Interference Matrix for a Coded Signal Processing Engine," the entire contents and disclosure of which is hereby incorporated by reference herein.

As may be seen, the inputs for correlator 240 include: $\prod_{i,j} P_{s_i(j)}^\perp s_n$ – a product of the projection operators that remove the k interference signals and an estimate of the signal tracked in the baseline receiver where n specifies the signal index; and t_{k+1} – time offset for the $(k+1)$ th signal tracked in the baseline receiver. The outputs of correlator 240 include: *Info* – either bits transmitted or relative signal amplitude information, if required by the cancellation method; and *Power* – estimate of signal power that is used to determine the order of the serial cancellation and to determine whether signal cancellation is required for the acquisition and/or tracking of particular signals.

10

If the data has been operated on by a projection operator in another processing finger's CSPE block 250, in order to remove an interference signal(s), it will be necessary to use the projection operator(s) in the creation of a reference signal for correlation purposes. This is illustrated as one of the inputs in 232. The output of correlator 240 is illustrated by element 244 and comprises power and other signal information, as discussed above. Correlator 240 may be modified as desired to achieve particular network requirements.

To track signal s_l from the original data \mathbf{y} , the data is correlated with a reference signal for s_l in block 240. However, to track a signal s_n after k interference signals have been removed, data is correlated with a reference signal $s_n^{(k)}$, which is produced after multiplying the original s_n by the k corresponding projection operators, or by the reference signal $s_n^{(k-1)}$. The flexibility in being able to use two different reference signals, i.e. either $s_n^{(k)}$ or $s_n^{(k-1)}$, for the correlation operation with $\mathbf{y}^{(i)}$, where $i > 0$, is due to the idempotent nature of projection matrices, i.e., $(\mathbf{P}_S^\perp)^T(\mathbf{P}_S^\perp) = \mathbf{P}_S^\perp$.

25

For example, consider the correlation $\mathbf{s}_2^{(1)T} \mathbf{y}^{(1)}$:

$$\mathbf{s}_2^{(1)T} \mathbf{y}^{(1)} = (\mathbf{P}_{S_1}^\perp \mathbf{s}_2)^T (\mathbf{P}_{S_1}^\perp \mathbf{y}) = \mathbf{s}_2^T \mathbf{P}_{S_1}^{\perp T} \mathbf{P}_{S_1}^\perp \mathbf{y} = \mathbf{s}_2^T \mathbf{P}_{S_1}^\perp \mathbf{y} = \mathbf{s}_2^T (\mathbf{P}_{S_1}^\perp \mathbf{y}) = \mathbf{s}_2^T \mathbf{y}^{(1)} \quad (9)$$

In general, the reference signal being correlated with the measured data may either have as many projection operators applied to it as the measured data or all but the last projection operator. Consider the following correlation:

$$\begin{aligned}
\mathbf{s}_m^{(n)T} \mathbf{y}^{(n)} &= \\
&= (\mathbf{P}_{S_n} \cdot \mathbf{P}_{S_{n-1}} \cdot \dots \cdot \mathbf{P}_{S_1} \mathbf{s}_m)^T (\mathbf{P}_{S_n} \cdot \mathbf{P}_{S_{n-1}} \cdot \dots \cdot \mathbf{P}_{S_1} \mathbf{y}) \\
&= \mathbf{s}_m^T \mathbf{P}_{S_1}^T \cdot \dots \cdot \mathbf{P}_{S_{n-1}}^T \cdot \mathbf{P}_{S_n}^T \mathbf{P}_{S_n} \cdot \mathbf{P}_{S_{n-1}} \cdot \dots \cdot \mathbf{P}_{S_1} \mathbf{y} \\
&= \mathbf{s}_m^T \mathbf{P}_{S_1}^T \cdot \dots \cdot \mathbf{P}_{S_{n-1}}^T \cdot \mathbf{P}_{S_n} \cdot \mathbf{P}_{S_{n-1}} \cdot \dots \cdot \mathbf{P}_{S_1} \mathbf{y} \\
&= (\mathbf{P}_{S_{n-1}} \cdot \mathbf{P}_{S_{n-2}} \cdot \dots \cdot \mathbf{P}_{S_1} \mathbf{s}_m)^T (\mathbf{P}_{S_n} \cdot \mathbf{P}_{S_{n-1}} \cdot \dots \cdot \mathbf{P}_{S_1} \mathbf{y}) \\
&= \mathbf{s}_m^{(n-1)T} \mathbf{y}^{(n)}
\end{aligned} \tag{10}$$

- 5 Both the correlation $\mathbf{s}_m^{(n)T} \mathbf{y}^{(n)}$ and the correlation $\mathbf{s}_m^{(n-1)T} \mathbf{y}^{(n)}$ are mathematically equivalent, though the latter is computationally more efficient since it requires the application of one fewer projection matrix.

10 Application of a projection operator to a reference signal is straightforward when the symbol boundaries, of the signal to be cancelled, align with the boundaries of the signal for which one is looking, or the signal for which one is looking has no symbol boundaries. For example, when acquiring and tracking a signal using a pilot channel over a segment length equivalent to one Walsh symbol in cdmaOne and cdma2000, the symbol boundaries are not relevant since Walsh code zero, used for the pilot, is all zeros. However, misalignment issues may arise for signals with symbol boundaries
15 when applying a projection operator to a reference signal.

CSPE block 250 (shown in Figure 2) provides interference mitigation by generating a projection operator \mathbf{P}_s^\perp to cancel the interfering signals represented in the matrix \mathbf{S} :
20

$$\mathbf{P}_s^\perp = \mathbf{I} - \mathbf{S} (\mathbf{S}^T \mathbf{S})^{-1} \mathbf{S}^T \tag{11}$$

The operator \mathbf{P}_s^\perp removes the signals in the interference matrix \mathbf{S} from the input data \mathbf{y} .

$$\mathbf{P}_s^\perp \mathbf{y} = \mathbf{y} - \mathbf{S} (\mathbf{S}^T \mathbf{S})^{-1} \mathbf{S}^T \mathbf{y} \tag{12}$$

In the serial canceller, the matrix \mathbf{S} consists of the signal \mathbf{s} tracked in the current processing finger and all channels to be cancelled. The processed data $\mathbf{y}^{(k+1)}$ and the projection operator $P_{s_n^{(k)}}^\perp$ are sent to the control module for processing by subsequent

fingers. The inputs for CSPE include: $\prod_{i,j} P_{s_i^{(j)}}^\perp s_n$ — a product of the projection

5 operators, used to remove the k interference signals, and the signal tracked in the baseline receiver where the n specifies the signal index; t_{k+1} — time offset for the $(k+1)$ th signal tracked in the baseline receiver; and, if required, *Info*— either bits transmitted or relative signal amplitude information. The outputs for CSPE include: $s_n^{(k)}$ — an estimate (reference signal) of the signal currently tracked in the processing finger; $\mathbf{y}^{(k)}$ — a
10 processed data stream in which k interference signals have been removed; $\mathbf{y}^{(k+1)}$ — a processed data stream in which $k+1$ interference signals have been removed including the signal currently being tracked; t_{k+1} — time delay for the $(k+1)$ th signal tracked in the baseline receiver; and $P_{s_n^{(k)}}^\perp$ — projection operator for the removal of $s_n^{(k)}$.

15 For a detailed description of the CSPE, the reader is referred to U.S. Provisional Patent Application No. 60/331,480, entitled “Construction of an Interference Matrix for a Coded Signal Processing Engine,” filed November 16, 2001; U.S. Patent Application No. 09/988,218, entitled “Interference Cancellation In a Signal,” filed November 19, 2001; U.S. Patent Application No. 09/988,219, entitled “A Method and Apparatus for
20 Implementing Projections in Signal Processing Applications,” filed November 19, 2001; U.S. Provisional Patent Application No. 60/326,199, entitled “Interference Cancellation in a Signal,” filed October 2, 2001; U.S. Provisional Patent Application No. 60/325,215, entitled “An Apparatus for Implementing Projections in Signal Processing Applications,” filed September 28, 2001; U.S. Provisional Patent Application No.
25 60/251,432, entitled “Architecture for Acquiring, Tracking and Demodulating Pseudorandom Coded Signals in the Presence of Interference,” filed December 4, 2000; U.S. Patent Application No. 09/612,602, filed July 7, 2000; and to U.S. Patent Application No. 09/137,183, filed August 20, 1998. The entire disclosures and contents of these applications are hereby incorporated by reference.

A system has herein been discussed in which the symbol boundaries are aligned. It should be appreciated that the teachings of the present invention may be utilized even if the signal boundaries are not aligned. Figure 3 is a depiction of how a projection operator may be applied to a reference signal when symbol boundaries of a signal being cancelled are not aligned with the reference symbol boundaries of the signal of interest.

Consider two signals s_1 (310) and s_2 (360), illustrated in Figure 3, where s_1 is canceled to demodulate s_2 . As seen in Figure 3, the symbol boundaries for s_1 and s_2 are not aligned and are offset by Δ_n . As a result, the projection operator, constructed to cancel s_1 , is applied to the s_2 reference signal such that it is aligned to the boundaries of s_1 340, 342 344 and 346. However, when s_2 is demodulated, the segment used for correlation is aligned to the boundaries of s_2 380, 382, 384 and 386. Projection operators 320, 322, 324 and 326 are constructed over segments aligned with symbol boundaries of s_1 and applied to s_2 resulting in segments 330, 332, 334 and 336. However, in order to demodulate s_2 , it is necessary to correlate over segments 370, 372 and 374.

The correlation for demodulation may be written as

$$(\tilde{\mathbf{P}}_{s_1}^\perp \mathbf{s}_2)^T (\tilde{\mathbf{P}}_{s_1}^\perp \mathbf{y}) \quad (13)$$

where the ‘ \sim ’ denotes that the projection operator is aligned to the symbol boundaries of s_2 rather than with s_1 . As a result, $\tilde{\mathbf{P}}_{s_1}^\perp$ is mathematically not a true projection operator. Instead, it is composed of portions of two adjacent $\mathbf{P}_{s_1}^\perp$ operators that comprise the upper and lower portions of the $\tilde{\mathbf{P}}_{s_1}^\perp$ matrix. Since, in general, the resulting matrix is not a true projection matrix, it is not guaranteed to be idempotent. Therefore, in the case of demodulation with misalignment between what is being cancelled and what is being demodulated, the following statement is, in general, *not* true:

$$\mathbf{s}_m^{(n)T} \mathbf{y}^{(n)} = \mathbf{s}_m^{(n-1)T} \mathbf{y}^{(n)} \quad (14)$$

Mathematically, it will then be necessary to always have the index n , corresponding to the projection operators, match between the data and the reference signal for demodulation purposes. In CDMA communication systems that use a pilot channel, acquisition and tracking of the pilot channel will be unaffected for a segment length corresponding to one Walsh symbol, since it is a non-information bearing channel with no symbol boundaries, and may exploit the idempotency of the projection operators by aligning with the segment corresponding to the projection operator.

Another method, which would require a greater amount of computation and require either bit or amplitude information, is to cancel signal s_1 from the data \mathbf{y} to detect signal s_2 , determine the alignment of the symbol boundaries of signal s_2 , rebuild the projection operator to remove s_1 from \mathbf{y} aligned to the symbol boundaries of s_2 and then correlate s_2 over the segment corresponding to the boundaries of s_2 . Using this method would preserve idempotency even with misalignment between what is being cancelled and what is being detected. Therefore, in the case of demodulation with misalignment between what is being cancelled and what is being demodulated, the following statement is, in general, true for this method:

$$\mathbf{s}_m^{(n)T} \mathbf{y}^{(n)} = \mathbf{s}_m^{(n-1)T} \mathbf{y}^{(n)} \quad (15)$$

20

However, from an implementation perspective, the correlation $\mathbf{s}_m^{(n)T} \mathbf{y}^{(n)}$ may be replaced by the correlation $\mathbf{s}_m^T \mathbf{y}^{(n)}$ where the projection operator(s) are not applied to the reference signal. Interference and the near-far effect are due to non-orthogonality of signals and a large disparity in power. If the signals that are cancelled are relatively orthogonal to the signal of interest, the projection operators have little effect on the reference signal for the signal of interest. As a result, the subspace angle between $\mathbf{s}_m^{(n)}$ and \mathbf{s}_m is quite small and the vectors are similar. Therefore, the correlations $\mathbf{s}_m^{(n)T} \mathbf{y}^{(n)}$ and $\mathbf{s}_m^T \mathbf{y}^{(n)}$ may likely yield similar results. In the present invention, this may be exploited whenever a projection operator or product of projection operators are applied

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to a reference signal, *e.g.*, demodulation of data; determination of active channel, bits or amplitude information; and construction of the interference matrix, greatly simplifying the implementation.

5

Processing the data

Suppose that the received data is composed of m signals ordered in terms of power from highest to lowest with additive white Gaussian noise (AWGN). The data y may be written as

$$y = s_1\theta_1 + s_2\theta_2 + s_3\theta_3 + \dots + s_{m-1}\theta_{m-1} + s_m\theta_m + n \quad (16)$$

10 where s_i denotes the i th signal, θ_i denotes the i th amplitude and n represents the noise term. Note a slight departure from previous convention in the prior art section where \mathbf{H} , s , θ and ϕ were used. This change eliminates the need for \mathbf{H} to be re-defined after each serial cancellation operation.

15

The following procedure is an example of how the data processing may proceed. There is a minimum one segment computational delay between each processing finger in which a signal is removed. It is necessary to create a reference signal over an entire segment before it is cancelled from the measured data. Subsequently, another processing finger may process that segment of data with the previous signal removed.

20

Figure 4 depicts processing delay due to the misalignment of symbol boundaries between fingers. The vertical lines occur at symbol boundaries, however, there may be more than one symbol per segment. Figure 4 shows finger 1, illustrated as reference numeral 410 and having segments 412, 414, 416, 418; finger 2, illustrated as reference numeral 420 and having segments 422, 424, 426, 428; and finger 3, illustrated as reference numeral 430 and having segments 432, 434, 436, 438 where time increases in the direction of increasing segment reference number. The segments for each finger are misaligned as illustrated by the dashed lines. In order to process segment 422 with the interference of finger 1 (410) removed it is necessary to have processed segments 412 and 414. Similarly, to process segment 424 with the interference of finger 1 (410)

25

30

removed it is necessary to have processed segments 414 and 416. Furthermore, in order to process segment 432 with fingers 1 (410) and 2 (420) removed it is necessary to have processed segments 422 and 424 which subsequently require the processing of segments 412, 414 and 416. Effectively, there may be at least a one-segment delay between each
5 finger in which a cancellation occurs.

When a receiver begins processing the data stream, the control block arbitrarily assigns reception of the strongest signal to a processing finger, hereafter referred to as the first processing finger. Moreover, processing fingers that track subsequent signals
10 will be referred to as the second processing finger, the third processing finger, . . . , n th processing finger, respectively. Relative finger power may change during processing and either the fingers may be re-assigned to maintain a particular ordering of power or the control block may maintain a record of the order in terms of power and process accordingly.

15

First Processing Finger:

Control block 206 sends the raw received signal data y , but no P_S^\perp information or time t information to the finger processing block 260 and y to CSPE block 250. Baseline block 230 calculates an estimate of the parameters corresponding to the signal
20 of interest by correlating with a generated reference signal s_1 and the signal, offset delay t_1 and potentially the phase and doppler frequency to CSPE block 250 and correlator block 240. CSPE block 250 generates the projection operator $P_{s_1}^\perp$ and operates on the data y to produce the processed data $y^{(1)}$ with the first signal removed.

25

$$P_{s_1}^\perp = I - s_1(s_1^T s_1)^{-1} s_1^T \quad (17)$$

$$y^{(1)} = P_{s_1}^\perp y \quad (18)$$

$$y^{(1)} = P_{s_1}^\perp s_1 \theta_1 + P_{s_1}^\perp s_2 \theta_2 + P_{s_1}^\perp s_3 \theta_3 + \dots + P_{s_1}^\perp s_{m-1} \theta_{m-1} + P_{s_1}^\perp s_m \theta_m + P_{s_1}^\perp n \quad (19)$$

$$y^{(1)} = P_{s_1}^\perp s_2 \theta_2 + P_{s_1}^\perp s_3 \theta_3 + \dots + P_{s_1}^\perp s_{m-1} \theta_{m-1} + P_{s_1}^\perp s_m \theta_m + P_{s_1}^\perp n \quad (20)$$

For simplicity, any nonzero multiplicative operation on the noise term \mathbf{n} will produce a product \mathbf{n} , *i.e.*, $X\mathbf{n} = \mathbf{n}$. Moreover, $s_i^{(1)}$ is defined as $s_i^{(1)} = P_{s_1}^\perp s_i$.

$$5 \quad \mathbf{y}^{(1)} = s_2^{(1)}\theta_2 + s_3^{(1)}\theta_3 + \dots + s_{m-1}^{(1)}\theta_{m-1} + s_m^{(1)}\theta_m + \mathbf{n} \quad (21)$$

CSPE block 250 sends the signal s_I and \mathbf{y} to the combiner (not illustrated), if necessary, and the Viterbi decoder. In addition, $\mathbf{y}^{(1)}$, $P_{s_1}^\perp$ and t_1 are sent to control block 206. Correlator block 240 calculates a power measurement P and the *Info* term that is sent to
10 control block 206.

After the first processing finger acquires and tracks the strongest signal, control block 206 will attempt to acquire and track a second signal (multipath of first signal or a second transmitter). Control block 206 will make the determination of whether the
15 acquisition procedure will operate on processed data with the strongest signal removed or if it will operate on the original data. This will determine which data and parameters are passed to the second processing finger.

Second Processing Finger:

20 According to an embodiment of the present invention, without loss of generality, the control block sends the processed data $\mathbf{y}^{(1)}$, $P_{s_1}^\perp$ and the time offset information t_1 to the baseline finger processing block and $\mathbf{y}^{(1)}$ to the CSPE block to effectively find a second signal with the strongest signal cancelled. The baseline finger processing block calculates an estimate of the next strongest signal by correlating with either the
25 generated reference signal $s_2^{(1)} = P_{s_1}^\perp s_2$ or s_2 and sends the signal and offset delay t_2 to the CSPE and correlator blocks. The CSPE block generates the projection operator $P_{s_2^{(1)}}^\perp$ and operates on the data $\mathbf{y}^{(1)}$ to produce the processed data $\mathbf{y}^{(2)}$ that has the second signal removed.

$$P_{s_2^{(1)}}^\perp = I - s_2^{(1)}(s_2^{(1)T} s_2^{(1)})^{-1} s_2^{(1)T} \quad (22)$$

$$y^{(2)} = P_{s_2^{(1)}}^\perp y^{(1)} = P_{s_2^{(1)}}^\perp P_{s_1}^\perp y \quad (23)$$

$$y^{(2)} = P_{s_2^{(1)}}^\perp s_2^{(1)} \theta_2 + P_{s_2^{(1)}}^\perp s_3^{(1)} \theta_3 + P_{s_2^{(1)}}^\perp s_4^{(1)} \theta_4 + \dots + P_{s_2^{(1)}}^\perp s_{m-1}^{(1)} \theta_{m-1} + P_{s_2^{(1)}}^\perp s_m^{(1)} \theta_m + P_{s_2^{(1)}}^\perp n \quad (24)$$

$$y^{(2)} = s_3^{(2)} \theta_3 + s_4^{(2)} \theta_4 + \dots + s_{m-1}^{(2)} \theta_{m-1} + s_m^{(2)} \theta_m + n \quad (25)$$

The CSPE block sends the signal $s_2^{(1)}$ and $y^{(k)}$ to the Viterbi decoder while $y^{(2)}$, $P_{s_2^{(1)}}^\perp$ and t_2 are sent to the control block. The correlator block calculates the power measurement term P and the *Info* term that may be subsequently sent to the control block.

The control block continues to compare the power measurement of the two transmitters. If the second measurement exceeds the power of the first, the control flow may change and the two processing fingers of the receiver will effectively switch roles. Namely, signal two will be removed from the data (if necessary) and then either the processed data or original signal will be sent to the processing finger operating on the first signal.

After the second finger acquires and tracks the next strongest signal, the control block will attempt to acquire and track a third signal (multipath of the first or second signal or a second or third transmitter). The control block will make the determination of whether the acquisition procedure will operate on the data with either the two strongest signals removed, one of them removed or if it will operate on the original data. This will determine which data and parameters are passed to the third processing finger.

Third Processing Finger:

According to an embodiment of the present invention, without loss of generality, the second signal does not need to be removed and the control block sends the processed data $y^{(1)}$, $P_{s_1}^\perp$ and the time delay information t_2 to the baseline receiver block and $y^{(1)}$ to the CSPE block to effectively find the third strongest signal with the signal in processing finger 1 removed. The baseline finger processing block calculates an estimate of the next strongest signal by correlating with a generated reference signal $s_3^{(1)} = P_{s_1}^\perp s_3$ or s_3 and sends the reference signal and offset delay t_3 to the CSPE and correlator blocks. The CSPE block generates the projection operator $P_{s_3^{(1)}}^\perp$ and operates on the data $y^{(1)}$ to produce the processed data $y^{(2')}$ that has the first and third signals removed. The prime denotes that different signals were cancelled than in the previous processing finger case, *i.e.*, (2') refers to the cancellation of processing fingers 1 and 2 whereas (2'') refers to the cancellation of processing fingers 1 and 3.

$$P_{s_3^{(1)}}^\perp = I - s_3^{(1)} (s_3^{(1)T} s_3^{(1)})^{-1} s_3^{(1)T} \quad (26)$$

$$y^{(2')} = P_{s_3^{(1)}}^\perp y^{(1)} = P_{s_3^{(1)}}^\perp P_{s_1}^\perp y \quad (27)$$

$$y^{(2')} = P_{s_3^{(1)}}^\perp s_2^{(1)} \theta_2 + P_{s_3^{(1)}}^\perp s_3^{(1)} \theta_3 + P_{s_3^{(1)}}^\perp s_4^{(1)} \theta_4 + \dots + P_{s_3^{(1)}}^\perp s_{m-1}^{(1)} \theta_{m-1} + P_{s_3^{(1)}}^\perp s_m^{(1)} \theta_m + P_{s_3^{(1)}}^\perp n \quad (28)$$

$$y^{(2'')} = s_2^{(2'')} \theta_2 + s_4^{(2'')} \theta_4 + \dots + s_{m-1}^{(2'')} \theta_{m-1} + s_m^{(2'')} \theta_m + n \quad (29)$$

20

The CSPE block sends the signal $s_3^{(1)}$ and $y^{(1)}$ to the Viterbi decoder while $y^{(2')}$, $P_{s_3^{(1)}}^\perp$ and t_3 are sent to the control block. The correlator block calculates a power measurement P and the *Info* term that may be subsequently sent to the control block.

25

The control block continues to compare the power measurement of the three transmitters. If the relative powers switch order, then the control flow may change and the appropriate processing fingers of the receiver will effectively switch roles.

Moreover, the CSPE may be turned on or off depending on the power requirements and the level of interference.

Effectively, this procedure may be continued for an arbitrary number of
5 processing fingers. Consider the nth processing finger in this process.

Nth processing finger:

According to an embodiment of the present invention, without loss of generality,
the control block sends the processed data $y^{(k)}$ with k ($k < n$) signals removed, the product
10 of the corresponding k projection operators $\prod_{i,j} P_{s_i^{(j)}}^\perp$ and the time offset
information t_{n-1} to the baseline receiver block and $y^{(k)}$ to the CSPE block to effectively
find the nth strongest signal with k signals removed. The baseline block calculates an
estimate of the tracking parameters of the next strongest signal by correlating with a
generated reference signal $s_n^{(k)} = \prod_{i,j} P_{s_i^{(j)}}^\perp s_n$ and sends the signal and offset delay t_n to
15 the CSPE and correlator blocks. The CSPE block generates the projection operator
 $P_{s_n^{(k)}}^\perp$ and operates on the data $y^{(k)}$ to produce the processed data $y^{(k+1)}$ that has the nth
signal removed.

$$P_{s_n^{(k)}}^\perp = I - s_n^{(k)} (s_n^{(k)T} s_n^{(k)})^{-1} s_n^{(k)T} \quad (30)$$

$$20 \quad y^{(k+1)} = P_{s_n^{(k)}}^\perp y^{(k)} = \prod_{i,j} P_{s_i^{(j)}}^\perp y \quad (31)$$

$$\begin{aligned} y^{(k+1)} = & P_{s_n^{(k)}}^\perp s_1^{(k)} \theta_1 + \dots + P_{s_n^{(k)}}^\perp s_{n-1}^{(k)} \theta_{n-1} + P_{s_n^{(k)}}^\perp s_n^{(k)} \theta_n + P_{s_n^{(k)}}^\perp s_{n+1}^{(k)} \theta_{n+1} + \dots \\ & + P_{s_n^{(k)}}^\perp s_m^{(k)} \theta_m + P_{s_n^{(k)}}^\perp n \end{aligned} \quad (32)$$

where k signals have been removed from the first n signals.

$$y^{(k+1)} = s_1^{(k+1)} \theta_1 + \dots + s_{n-1}^{(k+1)} \theta_{n-1} + s_{n+1}^{(k+1)} \theta_{n+1} + \dots + s_m^{(k+1)} \theta_m + n \quad (33)$$

The CSPE block sends the signal $s_n^{(k)}$ and $y^{(k)}$ to the Viterbi decoder while $y^{(k+1)}$, $P_{s_n^{(k)}}$ and t_n are sent to the control block. The correlator block calculates a power measurement P and the *info* term that is subsequently sent to the control block.

5 The control block continues to compare the power measurement of all the transmitters that are being tracked. If the ordering of the fingers, based on their relative power, changes, then the control flow may change and the appropriate processing fingers of the receiver will effectively switch roles. Moreover, the CSPE may be turned on or off for particular fingers depending on the power requirements and the amount of
10 interference.

The following particular embodiments present the cdmaOne forward link serial CSPE canceling receiver and the cdma2000 forward link serial CSPE canceling receiver, respectively.

15

Example I

The following embodiment is the cdmaOne (IS-95) forward link receiver. The cdmaOne serial cancellation CSPE receiver incorporates the coded signal-processing engine (CSPE) into a cdmaOne receiver architecture in which interference cancellation is performed in a serial manner as described above. Specifically, interference cancellation operations of single fingers, *e.g.*, one or more channels from a LOS or multipath signal, are performed in a serial, or cascading, manner, typically ordered in terms of power from highest to lowest. Each processing finger may operate on the
20 received data y or on processed data in which one or more interference signals have been cancelled. The benefit of this serial approach is that a serial receiver processing-finger may track and demodulate a signal that may otherwise be buried beneath the interference and may be undetectable by a baseline receiver. A master control module controls data flow and control signals for all processing fingers. Depending on the
25

power of the signals that are to be acquired, the CSPE may or may not cancel the interference of the previous signal(s).

Figure 5 depicts a forward link receiver 500. An RF signal 502 is received by antenna 504 and then is down-converted by converter 510 from RF to base-band (BB) based on a nominal carrier frequency. It should be appreciated that the present invention encompasses receivers that process either base-band or IF. The base-band signal is then sampled in an analog to digital converter (A/D) 520 to create a digital signal. Control module 530 feeds the digital signal into searcher 540, which acquires the strongest signal finger and communicates the short code offset and possibly the Doppler frequency to control module 530. Searcher 540 continues to search over the code offsets in order to acquire another signal. Control module 530 feeds the data and acquisition information into one of the four processing fingers 550, 560, 570 and 580, respectively. While Figure 5 depicts four processing fingers, the present invention is not limited to a specific number of processing fingers but instead applies to an arbitrary number of fingers.

Without loss of generality, assume for this example that the finger is assigned to finger processor 550. The finger processor tracks the finger, demodulates the signal, creates an interference matrix to cancel the signal and finally removes the signal from the input data signal. The demodulated signal is fed to demodulation module 590 that performs the Rake receiver combining as needed for multipath signals. The interference matrix and processed data are fed back to control module 530.

With information from searcher 540 and the neighbor list for the finger tracked in processing finger 550, control module 530 will decide whether to track a multipath associated with the finger currently tracked in processing finger 550 or the signal of another base station. Control module 530 has searcher 540 search over the code offsets for other strong signals in either the received data or in the data with the interfering finger removed. The latter is done if the interference from the first signal is too strong to detect another signal or the removal will facilitate acquisition. Without loss of

generality, the second finger is fed to finger processor 560 with data that has the strong signal removed. The signal is tracked, demodulated, an interference matrix is created and the signal is removed from the input data signal. The resulting signal has the first two tracked signals removed from it in a serial manner, *i.e.*, successive cancellations.

5

The process continues in a similar manner for the other finger processors. Searcher 540 may search the received data or data in which interference signal(s) have been removed in a serial manner. Multipath signals corresponding to the same base station are combined in a Rake receiver in module 590.

10

In Figure 6, a searcher 600 (such as that shown previously in Figure 5, element 540) is discussed in greater detail. The pilot Walsh code, which is all zeros, is multiplied by the short code in multiplier 610. If the input data y has had interference signals removed, then the product of multiplier 610 is multiplied by the corresponding projection matrices in multiplier 620. The reference signal computed in 620 is multiplied by the input data signal y in multiplier 630. The correlation procedure is completed by summing the product of y and the reference signal over a correlation length N in summation block 640. The short code multiplied in multiplication block 610 is chosen such that the reference signal checks all possible code offsets.

20

Comparator 650 uses standard methods to select the strongest signal. However, if a processing finger is already tracking a signal then that signal will not be reacquired. Moreover, if the receiver has enough signals (LOS and/or multipath signals) from one base station, the searcher may be instructed to not acquire any more multipath signals from the same base station. Depending on the searching algorithm, the control module may provide the searcher with either an unprocessed signal or one in which interference signal(s) have been removed.

25

In Figure 7, a processing finger 700 (such as that shown previously in Figure 5, element 550) is discussed in greater detail. The parameters associated with the input signal y are refined in tracking loop(s) 710. Tracking loop(s) 710 may include a delay-

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locked loop (DLL) or code offset estimation, a phase-locked loop (PLL) or phase estimation and/or a frequency-locked loop (FLL) or frequency estimation. At this point, this embodiment of the present invention differs from the standard baseline cdmaOne receiver architecture. The data flow is split between the architecture for signal demodulation and the CSPE architecture 760 for interference cancellation. Tracking loop(s) or estimation modules 710 refine the parameters for the reference signal generation used in the demodulation of the channel. After tracking loop(s) or estimation modules 710, the signal is de-spread by multiplying an appropriate short code spreading sequence and the phase is stripped in multiplier 720.

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The Walsh code of the desired channel is multiplied by a projection matrix or product of projection matrices in multiplier 730, if necessary, and is multiplied with the data signal in multiplier 740. The product of the data and the reference code is summed in summer 750 over one Walsh symbol. The demodulated data is then fed to a demodulation module, such as shown in Figure 5, element 590, where Rake receiver combining is performed when multipath signals from the same base station are being demodulated concurrently.

A modified Hadamard transform module 770 is applied to the de-spread data signal. The Walsh codes used for channelization in cdmaOne are derived from a rank 64 Hadamard matrix. Multiplication of the de-spread data with the appropriate row of the Hadamard matrix (Walsh symbol) and summing over one Walsh symbol effectively demodulates the corresponding channel. Hadamard transform module 770 demodulates all 64 channels in one finger. Since the processing finger may process both unprocessed data and data in which interference signal(s) have been removed, a projection matrix or product of projection matrices may have to be applied to the Walsh codes prior to multiplication with the data as indicated by element 772. Output 774 of this module is the signal amplitude of each channel. It is referred to as relative channel amplitude 774 in order to emphasize that it is not necessary to know the absolute signal amplitude for the CSPE, but instead the relative amplitude between channels in the same finger is sufficient.

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The generation of **S** module 780 has a lot of flexibility in terms of its implementation. The channels to be canceled from the data signal may be pre-set as a fixed-size subset of channels or the complete set of channels or it may be dynamically
5 determined from the relative channel amplitude output from Hadamard transform module 770 or another criteria. For example, a threshold may be set, such that all channels above this particular threshold are selected or a fixed number of channels may be chosen such that those channels with the greatest power are selected to be included in the generation of the **S** matrix. A control module, such as shown in Figure 5, element
10 530, also determines which method of cancellation is to be used, *i.e.*, sign information, relative power information for the composite method, no information, or the cancellation method may be fixed by the architecture. Reference signals are generated and used as vectors in the construction of the **S** matrix. If the input data is processed data, then a projection matrix or product of projection matrices 772 may be applied to
15 the reference signals. The output of module 780 is the **S** matrix and the projection operator constructed from **S** that projects a signal onto a subspace orthogonal to the subspace of **S**. Module 790 applies the new projection operator (denoted by ‘*’) to the data signal. Processing finger 700 feeds the new projection operator and the processed data $\mathbf{y}^{(1)}$ to a control module, such as shown in Figure 5, element 530.

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In Figure 8, a modified Hadamard Transform module 800 (such as that shown in Figure 7, element 770) is discussed in greater detail. The input \mathbf{y} is split into 64 paths in order to correlate it with the 64 Walsh symbols and calculate an estimate of each channel’s amplitude. The 64 Walsh symbols are multiplied by the appropriate
25 projection matrix or product of projection matrices, if necessary. For example, see 801, 811 and 821. The result is then multiplied with \mathbf{y} in respective multipliers 802, 812 and 822 and summed over a Walsh symbol in respective summers 803, 813 and 823. The estimate of each channel’s amplitude, which is output, may be incorrect by a scale factor, but the relative amplitude between channels is correct.

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Figures 9, 10, 11 and 12 depict several examples of the generation of an **S** matrix. Figure 9 depicts the generation of **S** matrix 900 using no information of bits transmitted or relative signal amplitude. Each channel has a selector (901, 911 and 921) that determines which Walsh symbols (channels) will be removed from the data signal. If the data has been processed, *i.e.*, has had interference signals removed, then the appropriate projection matrix or product of projection matrices is applied to each Walsh symbol by the respective multipliers 902, 912 and 922. The reference vector output from each selected channel is included as a vector in interference matrix **S** 930. The ordering of the vectors does not matter.

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Figure 10 depicts the generation of **S** matrix 1000 using sign (bit) information from each channel. Each channel has a selector (1001, 1011 and 1021) that determines which Walsh symbols will be removed from the data signal. If the data has been processed then the appropriate projection matrix or product of projection matrices is applied to each Walsh symbol by respective multipliers 1002, 1012 and 1022. Relative amplitude information is processed by a module (1003, 1013 and 1023) in each channel to determine the sign of the bit transmitted. The sign information is multiplied in respective multipliers 1004, 1014 and 1024 with the results from respective multipliers 1002, 1012 and 1022. The reference vector output from each channel is included in interference matrix **S** 1030. The ordering of the vectors does not matter.

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Figure 11 depicts the generation of **S** matrix 1100 using relative amplitude information from each channel in order to use the composite method of cancellation. Each channel has a respective selector (1101, 1111 and 1121) that determines which Walsh symbols will be removed from the data signal. If the data has been processed then the appropriate projection matrix or product of projection matrices is applied to each Walsh symbol by the respective multiplier 1102, 1112 and 1122. Relative amplitude information is used to scale the result in each channel by the appropriate amount with the respective multipliers 1103, 1113 and 1123. The reference vector output from each channel is added together to form a composite vector in adder 1130. The resulting composite reference vector is included in interference matrix **S** 1140.

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Figures 12A and 12B depict two examples of the generation of an \mathbf{S} matrix, in which a combination of the above-described methods are utilized. Figure 12A shows a combination of using no information of bits transmitted or relative signal amplitude and the composite method and Figure 12B shows a combination of using relative amplitude information and the composite method.

In Figure 12A, each channel has a respective selector 1201, 1211 and 1221 that determines which Walsh symbol will be removed from the data signal without using bit or relative amplitude information. If the data has been processed then the appropriate projection matrix or product of projection matrices is applied to each Walsh symbol by respective multiplier 1202, 1212 and 1222. The reference vectors output from each channel is included in the interference matrix \mathbf{S} . Similarly, selectors 1206, 1216 and 1226 determine which Walsh symbols will be removed from the data signal using relative amplitude information and the composite method. If the data has been processed then the appropriate projection matrix or product of projection matrices is applied to each Walsh symbol by respective multiplier 1207, 1217 and 1227. Relative amplitude information is used to scale each reference vector appropriately by respective multiplier 1208, 1218 and 1228. The reference vector output from each channel is summed together by summer 1230 to form a composite vector that is included in interference matrix \mathbf{S} 1235. The ordering of the vectors in the \mathbf{S} matrix does not matter.

In Figure 12B, each channel has a respective selector 1251, 1261 and 1271 that determines which Walsh symbol will be removed from the data signal using sign information. If the data has been processed then the appropriate projection matrix or product of projection matrices is applied to each Walsh symbol by respective multiplier 1252, 1262 and 1272. Relative amplitude information is processed by respective modules 1253, 1263 and 1273 in each channel to determine the sign of the bit transmitted. The sign information is multiplied by respective multipliers 1254, 1264 and 1274 with the results from multipliers 1252, 1262 and 1272. The reference vector output from each channel is included in interference matrix \mathbf{S} 1285. Similarly,

respective selectors 1256, 1266 and 1276 determine which Walsh symbols will be removed from the data signal using the relative amplitude information and the composite method. If the data has been processed then the appropriate projection matrix or product of projection matrices is applied to each Walsh symbol by respective multipliers 1257, 1267 and 1277. Relative amplitude information is used to scale each reference vector appropriately by respective multipliers 1258, 1268 and 1278. The reference vector output from each channel is summed together to form a composite vector by summer 1280. This composite vector is included in interference matrix **S** 1285. The ordering of the vectors does not matter.

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Example II

The following embodiment is of the cdma2000 forward link receiver. Modifications have to be made to the cdmaOne embodiment to accommodate features and enhancements made in cdma2000. Quasi-orthogonal (QOF) and concatenated functions may be used to achieve a smaller impact on the number of orthogonal codes available for traffic channels. Variable length Walsh codes are also used to attain higher data rates. Specifically, shorter Walsh codes down to 4 chips in length are used to increase the data rate. The limitation on Walsh codes is a length limit of 128 for 1X rates and 256 for 3X rates, except for the auxiliary pilot and auxiliary transmit diversity pilot channels.

Due to the varying lengths of the Walsh codes it will become increasingly important to have bit or relative amplitude information to facilitate interference cancellation. If the interference matrix contains non-pilot interference vectors composed of different length Walsh codes, it becomes imperative that the vectors of shorter length Walsh codes use either bit or relative amplitude information in order to correctly cancel interference. For information bearing channels, it is necessary for no Walsh symbol boundaries to appear in the interference matrix if no bit or relative amplitude information is used. The benefit of canceling over a single Walsh symbol is that it is not necessary to know bit or relative amplitude information. However, it may

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not be feasible to cancel interference over only 4 chip symbols or if there is symbol misalignment since a longer data record may provide better cancellation properties.

5 Cross-correlation will have to be accounted for when a mix of QOFs and variable length Walsh codes are used for channelization. While the goal is to minimize the cross-correlation between QOFs and variable length Walsh codes, the codes are not truly orthogonal and there exists a nonzero correlation. Even with perfect time alignment, QOFs are not orthogonal to the original Walsh code set. Within a QOF set, orthogonality is preserved, but there is a cross-correlation between code vectors from
10 different sets. A critical difference is that when QOFs are used, channels within the same finger may no longer be orthogonal to each other. Therefore, the present invention may be applied to cancellation of channels within one finger.

Moreover, cdma2000 may use orthogonal transmit diversity (OTD) to mitigate
15 multipath effects. OTD splits the transmitted symbols into two paths where each path is spread by a different Walsh code or quasi-orthogonal function associated with each antenna. As a result, the receiver architecture depicts the separation of the I and Q channels to accommodate the application of different Walsh codes, if necessary. Moreover, it emphasizes the construction of separate interference matrices for the I and
20 Q channels for cancellation purposes.

The cdma2000 serial CSPE receiver incorporates the coded signal-processing engine (CSPE) into a cdma2000 receiver architecture in which interference cancellation is performed in a serial manner. Specifically, interference cancellation operations of
25 single fingers, *e.g.*, one or more channels from a LOS or multipath signal, are performed in a serial, or cascading, manner, typically ordered in terms of power from highest to lowest. Each processing finger may operate on the received data y or on processed data in which one or more interference signals have been cancelled. The benefit of this serial approach is that a serial receiver processing finger may track and demodulate a signal
30 that may otherwise be buried beneath the interference and be undetectable to a baseline receiver. A master control module controls data flow and control signals for all

processing fingers. Depending on the power of the signals that are to be acquired, the CSPE may or may not cancel the interference of the previous signal(s).

As discussed above, Figure 5 depicts a forward link receiver 500. Forward link receiver 500 architecture is applicable to both cdmaOne and cdma2000. An RF signal received by the antenna is down-converted in 510 from RF to base-band (BB) based on the nominal carrier frequency. The present embodiment encompasses receivers that process base-band or IF signals. The base-band signal is then sampled in 520 to create a digital signal. The I and Q channels are not shown explicitly, but are implicit in all the data connections in the figure. Control module 530 feeds the digital signal into searcher 540, which acquires the strongest signal finger and communicates the short code offset and possibly the Doppler frequency and/or phase to control module 530. Searcher 540 continues to search over the code offsets in order to acquire another signal. Control module 530 feeds the data and acquisition information into one of the four processing fingers 550, 560, 570 and 580. While Figure 5 depicts four processing fingers, the present embodiment is not limited to a specific number of processing fingers but instead applies to an arbitrary number of fingers.

Without loss of generality, suppose that the finger is assigned to finger processor 550. The finger processor tracks the finger, demodulates the signal, creates interference matrices to cancel the signal and finally removes the signal from the input data signal. The demodulated signal is fed to demodulation module 590 that performs the Rake receiver combining as needed for multipath signals. The interference matrices and processed data are fed back to control module 530.

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With information from searcher 540 and the neighbor list from the finger tracked in processing finger 550, control module 530 will decide whether to track a multipath associated with the finger currently tracked in processing finger 550 or another base station. Control module 530 has searcher 540 search over the code offsets for other strong signals in either the received data or in the data with the interfering finger removed. The latter is done if the interference from the first signal is too strong to

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detect or adequately track another signal. Without loss of generality, the second finger is fed to finger processor 560 with data that has the strong signal removed. The signal is tracked, demodulated, interference matrices are created and the signal is removed from the input data signal. Thus, the resulting signal has the first two tracked signals removed from it in a serial manner, *i.e.*, successive cancellations.

The process continues in a similar manner for the other finger processors. Searcher 540 may search the received data or data in which interference signal(s) have been removed in a serial manner. Multipath signals corresponding to the same base station are combined in a Rake receiver in module 590.

In Figure 13, searcher 1300 (such as that shown in Figure 5, element 540) is discussed in greater detail. The pilot Walsh code is multiplied by the short code by respective multipliers 1301 and 1311. If the input data y has had interference signals removed, then the products of the multiplications in multipliers 1301 and 1311 are multiplied by the corresponding projection matrices in the respective multipliers 1303 and 1313. The reference signals computed by multipliers 1303 and 1313 are multiplied in the respective multipliers 1305 and 1315 with the respective input data signals y_I and y_Q . The correlation procedure is completed by summing the products of the I and Q channels with the reference signals over a correlation length (N chips) by respective summers 1307 and 1317. The short code multiplied in multiplication blocks 1301 and 1311 are chosen such that the reference signal checks all possible code offsets.

Comparator 1309 uses standard methods to select the strongest signal. However, if a processing finger is already tracking a signal, then that signal will not be reacquired. Moreover, if the receiver has enough signals (LOS and/or multipath signals) from one base station, the searcher may be instructed to not acquire any more multipath signals from the same base station. Depending on the searching algorithm, the control module may provide the searcher with either an unprocessed signal or one in which interference signal(s) have been removed.

In Figure 14, a processing finger 1400 (such as that shown in Figure 5, element 550) is discussed in greater detail. The parameters of the input signals y_I and y_Q are further refined in tracking loop(s) or parameter estimation module(s) 1410. Tracking loop(s) or estimation module(s) 1410 may include a DLL or code offset estimation, a
5 PLL or phase estimation and/or an FLL or frequency estimation. At this point, this embodiment of the present invention differs from the standard baseline cdma2000 receiver architecture. The data flow is split between the architecture for signal demodulation and the CSPE architecture for interference cancellation in blocks 1440 and 1450.

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Tracking loop(s) or parameter estimation module(s) 1410 refine the parameters for the reference signal generation used in the demodulation of the channel. After 1410, the signals are de-spread by the appropriate short code spreading sequence by respective multipliers 1401 and 1421. The Walsh code, concatenated Walsh code or quasi-orthogonal function (QOF) of the desired channel is multiplied by a projection matrix or
15 product of projection matrices by respective multipliers 1403 and 1423, if necessary, and is then multiplied with the I and Q data signals by respective multipliers 1405 and 1425. The product of the data and the reference codes is summed by respective summers 1407 and 1427 over one Walsh or QOF symbol. The demodulated data is then
20 fed to a demodulation module, such as shown in Figure 5, element 590, where Rake receiver combining is performed when multipath signals from the same base station are demodulated.

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Amplitude estimator modules 1409 and 1429 are applied to the de-spread I and Q data signals. Variable length Walsh codes and QOFs are used for channelization in cdma2000. Walsh codes and QOFs are derived from an orthogonal Hadamard matrix. Multiplication of the de-spread data with the appropriate symbol and summing over a symbol length effectively demodulates the corresponding channel. The amplitude estimator demodulates all channels in one finger. Since the processing finger may
30 process both unprocessed data and data in which interference signal(s) have been removed, a projection matrix or product of projection matrices may have to be applied

to the symbols prior to multiplication with the data. The output of this module is the signal amplitude of each channel. It is referred to as relative channel amplitude in order to emphasize that it is not necessary to know the absolute signal amplitude for the CSPE, but instead the relative amplitude between channels in the same finger is sufficient.

The generation of S , modules 1411 and 1431, have a lot of flexibility in terms of their implementation. The channels to be canceled from the data signal can be pre-set as a fixed-size subset of channels or the complete set of channels or it may be dynamically determined from the relative channel amplitude output from the amplitude estimator modules 1409 and 1429. For example, a threshold may be set, such that all channels above this particular threshold are selected or a fixed number of channels may be chosen such that those with the greatest power are selected to be included in the generation of the S matrix. The control module also determines which method of cancellation is to be used, *i.e.*, sign information, relative power information for the composite method or no information, or it may be fixed in the architecture. Reference signals are generated and used as vectors in the construction of the S matrices. If the input data is processed data, then a projection matrix or product of projection matrices is applied to each of the reference signals. The output of modules 1411 and 1431 is the S matrix and the projection operator constructed from the S matrices that project the signals onto a subspace orthogonal to the subspace of each of the S matrices respectively. Modules 1413 and 1433 apply the new projection operators (denoted by ‘*’) to the data signals. The processing finger feeds the new projection operators and the processed data $y_I^{(1)}$ and $y_Q^{(1)}$ to the control module.

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In Figure 15, amplitude estimator modules 1500 and 1550 (such as those shown in Figure 14, elements 1409 and 1429) are discussed. The input data y_I and y_Q are considered separately and are correlated with Walsh and QOF symbols in order to calculate an estimate of each channel’s amplitude. In the figure, the symbols are denoted by W_i , which represents variable length Walsh codes and QOF symbols. The symbols are multiplied by the appropriate projection matrix or product of projection

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matrices, if necessary. For example, see respective multipliers 1501, 1511, 1551 and 1561. The result is then multiplied with y_1 by respective multipliers 1503 and 1513 and with y_Q by respective multipliers 1553 and 1563 and then summed over the symbol length in respective summers 1505, 1515, 1555 and 1565. The estimate of each channel's amplitude, which is output by the modules 1500 and 1550, may be off by a scale factor, but the correct relative amplitude between channels is all that is necessary.

Figures 16A, 16B, 17A, 17B, 18A and 18B depict several examples of 'generation of S' modules. Figures 16A and 16B depict the generation of S matrix modules 1600 and 1650 that use no information of bits transmitted or relative signal amplitude. Each channel has a respective selector 1601, 1611, 1651 and 1661 that determines which symbols (channels) will be removed from the data signal. If the data has been processed, *i.e.*, has had interference signals removed, then the appropriate projection matrix or product of projection matrices is applied to each symbol by respective multipliers 1603, 1613, 1653 and 1663. The reference vector output from each selected channel is included as a vector in the interference matrices S_I and S_Q , 1620 and 1670, respectively. The ordering of the vectors in the S matrices does not matter.

Figures 17A and 17B depict generation of S matrix modules 1700 and 1750 using sign (bit) information from each channel. Each channel has a respective selector 1701, 1711, 1751 and 1761 that determines which symbols (channels) will be removed from the data signals. If the data has been processed then the appropriate projection matrix or product of projection matrices is applied to each symbol by respective multipliers 1703, 1713, 1753 and 1763. Relative amplitude information is processed by a respective amplitude module 1705, 1715, 1755 and 1765 in each channel to determine the sign of the bit transmitted. The sign information multiplies the symbols in respective multipliers 1707, 1717, 1757 and 1767. The reference vector output from each channel is included in the interference matrices S_I and S_Q , 1720 and 1770, respectively. The ordering of the vectors does not matter.

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Figures 18A and 18B depict generation of S matrix modules 1800 and 1850 using relative amplitude information from each channel in order to use the composite method of cancellation. Each channel has a respective selector 1801, 1811, 1851 and 1861 that determines which symbols will be removed from the data signals. If the data
5 has been processed then the appropriate projection matrix or product of projection matrices is applied to each symbol by respective multipliers 1803, 1813, 1853 and 1863. Relative amplitude information is used to scale the result in each channel by respective multipliers 1805, 1815, 1855 and 1865 by an appropriate amount. The reference vector output from each channel is added together to form a composite vector by respective
10 adders 1820 and 1870 for the I and Q channels respectively. The resulting composite reference vectors are used to construct the S_I and S_Q interference matrices, 1830 and 1880, respectively.

The methods for constructing S matrices may be combined in the manner of
15 Figure 12, provided for the cdmaOne embodiment, for example, by combining the composite method with either the method using bit information or the method using neither bit nor relative signal amplitude.

The methods and apparatus of the present invention may be applied to other
20 CDMA communication embodiments, *e.g.*, WCDMA. Moreover, the present invention may be applied to global positioning systems, radar and optics.

Although the present invention has been fully described in conjunction with the preferred embodiment thereof with reference to the accompanying drawings, it is to be
25 understood that various changes and modifications may be apparent to those skilled in the art. Such changes and modifications are to be understood as included within the scope of the present invention as defined by the appended claims, unless they depart therefrom.

WHAT IS CLAIMED IS:

1. A serial receiver for a wireless communication system, said communication system comprising:
 - a means for receiving a signal y having data parameters;
 - a control processor; said control processor for receiving said signal y and said data parameters;
 - at least two fingers, said control processor for determining which of said data parameters are sent to respective fingers, wherein of said fingers, at least one is a search finger and at least one is a tracking finger; and
 - wherein said tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), said CSPE for interference cancellation in the reception of said signal y .
2. The serial receiver for a wireless communication system recited in claim 1, wherein said data parameters are selected from the group consisting of: data streams, time offsets, projection operators or corresponding interference matrices, power information, signal amplitude, and signal polarity.
3. The serial receiver for a wireless communication system recited in claim 2, wherein said data streams are at an intermediate frequency (IF).
4. The serial receiver for a wireless communication system recited in claim 2, wherein said data streams are at base-band (BB) frequency.
5. The serial receiver for a wireless communication system recited in claim 1, wherein said control processor has an output selected from the group consisting of: $y^{(k)}$, a data stream in which k interference signals have been removed; $\prod_{i,j} P_{s_i^{(j)}}^\perp$ – a product of a projection operator that is used to remove the k interference signals; and t_k , time offset for the k th interference signal.

6. The serial receiver for a wireless communication system recited in claim 1, wherein said search finger receives input from said control processor, said input being an unprocessed measured segment of data.

7. The serial receiver for a wireless communication system recited in claim 1, wherein said search finger receives an input from said control processor, said input being selected from the group consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$, a product of a projection operator used to remove the k interference signals.

8. The serial receiver for a wireless communication system recited in claim 1, wherein said search finger generates an output to said tracking finger.

9. The serial receiver for a wireless communication system recited in claim 8, wherein the search finger output is selected from the group consisting of: time offset and relative power information.

10. The serial receiver for a wireless communication system recited in claim 9, wherein said time offset is an approximation.

11. The serial receiver for a wireless communication system recited in claim 1, wherein said correlator correlates said signal \mathbf{y} with a reference signal for s_l , where s_l is the signal of interest.

12. The serial receiver for a wireless communication system recited in claim 1, wherein said correlator correlates said signal $\mathbf{y}^{(k)}$ with a reference signal $s_n^{(k)}$.

13. The serial receiver for a wireless communication system recited in claim 1, wherein said correlator correlates said signal $\mathbf{y}^{(k)}$ with a reference signal s_n .

14. The serial receiver for a wireless communication system recited in claim 12, wherein said reference signal $s_n^{(k)}$ is produced by multiplying reference signal s_n by the k corresponding projection operators.

15. The serial receiver for a wireless communication system recited in claim 12, wherein said reference signal equivalent to $s_n^{(k)}$ is produced by multiplying reference signal s_n by the (k-1) corresponding projection operators.

16. The serial receiver for a wireless communication system recited in claim 1, wherein said CSPE comprises: an apparatus for generating a projection operator and canceling interfering sources from a received signal (\mathbf{y}), said signal comprising s_i , a signal of the source of interest; $s_1, s_2, s_3, \dots, s_p$, signals of other interfering sources; and noise (\mathbf{n}); said apparatus comprising:

means for determining a basis vector \mathbf{U} ;

means for storing elements of said basis vector \mathbf{U} ; and

means for determining y_{perp} where: $\mathbf{y}_{\text{perp}} = \mathbf{y} - \mathbf{U}(\mathbf{U}^T \mathbf{U})^{-1} \mathbf{U}^T \mathbf{y}$.

17. The serial receiver for a wireless communication system recited in claim 1, wherein said CSPE comprises: an apparatus for generating a projection operator and canceling interfering sources from a received signal (\mathbf{y}), said signal comprising s_i , $s_1, s_2, s_3, \dots, s_p$, signals of other interfering sources; and noise (\mathbf{n}); the apparatus comprising:

A. means for assigning s_1 as a first basis vector \mathbf{u}_1 ;

B. means for determining σ_i , where $\mathbf{u}_i^T \mathbf{u}_i = \sigma_i$;

C. means for storing \mathbf{u}_i ;

D. means for computing inner products of the s_{i+1} and the \mathbf{u}_1 through \mathbf{u}_i vectors;

- E. means for multiplying said inner product with a respective scalar $1/\sigma_i$ and thereby creating a first intermediate product;
- F. means for scaling each respective basis vector u_i by multiplying each respective first intermediate product with each respective basis vector u_i ;
- G. means for serially subtracting said intermediate product from s_{i+1} ;
- H. means for utilizing the result from step G and subtracting the next incoming value of $u_i \frac{1}{\sigma_i} u_i^T s_{i+1}$ until all the values are processed;
- I. means for obtaining the next basis vector u_{i+1} from step H;
- J. means for comparing u_{i+1} to a predetermined value and if equal to or less than said value, going to step O;
- K. means for storing u_{i+1} ;
- L. means for determining an inner product of $u_{i+1}^T u_{i+1}$;
- M. means for determining the reciprocal of step K which is $1/\sigma_{i+1}$;
- N. means for storing $1/\sigma_{i+1}$;
- O. means for incrementing i ;
- P. means for conducting steps D through O until $i=p$, where p is the total number of said sources of interest; and
- Q. means for determining y_{perp} where: $y_{\text{perp}} = y - U(U^T U)^{-1} U^T y$.

18. A serial receiver for a wireless communication system, said communication system comprising:

a means for receiving a signal y having data parameters;

a control processor; said control processor for receiving said signal y and said data parameters;

at least two fingers, said control processor for determining which data parameters are sent to respective fingers, wherein of said fingers, at least one finger is a search finger and at least one finger is a tracking finger;

wherein said tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), said CSPE for interference cancellation in the reception of said measured signal;

wherein said CSPE comprises: an apparatus for generating a projection from a received signal (\mathbf{y}), said signal comprising \mathbf{s}_i , a signal of the source of interest; $\mathbf{s}_1, \mathbf{s}_2, \mathbf{s}_3, \dots, \mathbf{s}_p$ signals of other sources; and noise (\mathbf{n}); said apparatus comprising:

means for determining a basis vector \mathbf{U} ;

means for storing elements of said basis vector \mathbf{U} ;

means for determining \mathbf{y}_{perp} where: $\mathbf{y}_{\text{perp}} = \mathbf{y} - \mathbf{U}(\mathbf{U}^T \mathbf{U})^{-1} \mathbf{U}^T \mathbf{y}$; and

wherein said search finger receives an input from said control processor, said input being selected from the group consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$, a product of a projection operator used to remove the k interference signals.

19. The serial receiver for a wireless communication system recited in claim 18, wherein said data parameters are selected from the group consisting of: data streams, time offsets, projection operators or corresponding interference matrices, power information, signal amplitude, and signal polarity.

20. The serial receiver for a wireless communication system recited in claim 19, wherein said data streams are at an intermediate frequency (IF).

21. The serial receiver for a wireless communication system recited in claim 19, wherein said data streams are at base-band (BB) frequency.

22. The serial receiver for a wireless communication system recited in claim 18, wherein said control processor has an output selected from the group consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; $\prod_{i,j} P_{s_i^{(j)}}^\perp$ – a product of a projection operator that is used to remove the k interference signals; and t_k , time offset for the k th interference signal.

23. The serial receiver for a wireless communication system recited in claim 18, wherein said search finger receives input from said control processor, said input being an unprocessed measured segment of data.

24. The serial receiver for a wireless communication system recited in claim 18, wherein said search finger receives an input from said control processor, said input being selected from the group consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$, a product of projection operators used to remove the k interference signals.

25. The serial receiver for a wireless communication system recited in claim 18, wherein said search finger generates an output to said tracking finger.

26. The serial receiver for a wireless communication system recited in claim 25, wherein the search finger output is selected from the group consisting of: time offset and relative power information.

27. The serial receiver for a wireless communication system recited in claim 26, wherein said time offset is an approximation.

28. The serial receiver for a wireless communication system recited in claim 18, wherein said correlator correlates said signal \mathbf{y} with a reference signal for s_l , where s_l is the signal of interest.

29. The serial receiver for a wireless communication system recited in claim 18, wherein said correlator correlates said signal $\mathbf{y}^{(k)}$ with a reference signal $s_n^{(k)}$.

30. The serial receiver for a wireless communication system recited in claim 18, wherein said correlator correlates said signal $\mathbf{y}^{(k)}$ with a reference signal s_n .

31. The serial receiver for a wireless communication system recited in claim 29 wherein said reference signal $s_n^{(k)}$ is produced by multiplying an original reference signal s_n by the k corresponding projection operators.

32. The serial receiver for a wireless communication system recited in claim 29, wherein said reference signal equivalent to $s_n^{(k)}$ is produced by multiplying an original reference signal s_n by the $k-1$ corresponding projection operators.

33. A serial receiver for a wireless communication system, said communication system comprising:

a means for receiving a signal y having data parameters;

a control processor; said control processor for receiving said signal y and said data parameters;

at least two fingers, said control processor for determining which of said data parameters are sent to respective fingers, wherein of said fingers, at least one is a search finger and at least one is a tracking finger;

wherein said tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), said CSPE for interference cancellation in the reception of said measured signal;

wherein said CSPE comprises: an apparatus for generating a projection from a received signal (y), said signal comprising s_i , a spread signal matrix of the source of interest; $s_1, s_2, s_3, \dots, s_p$, signals of other interfering sources; and noise (n); the apparatus comprising:

A. means for assigning s_1 as a first basis vector u_1 ;

B. means for determining σ_i , where $\mathbf{u}_i^T \mathbf{u}_i = \sigma_i$;

C. means for storing u_i ;

D. means for computing inner products of the s_{i+1} and the u_1 through u_i vectors;

- E. means for multiplying said inner products with a respective scalar $1/\sigma_i$ and thereby creating a first intermediate product;
- F. means for scaling each respective basis vector u_i by multiplying each respective first intermediate product with each respective basis vector u_i ;
- G. means for serially subtracting said intermediate product from s_{i+1} ;
- H. means for utilizing the result from step G and subtracting the next incoming value of $\mathbf{u}_i \frac{1}{\sigma_i} \mathbf{u}_i^T \mathbf{s}_{i+1}$ until all the values are processed;
- I. means for obtaining the next basis vector u_{i+1} from step H;
- J. means for comparing u_{i+1} to a predetermined value and if equal to or less than said value, going to step O;
- K. means for storing u_{i+1} ;
- L. means for determining an inner product of $\mathbf{u}_{i+1}^T \mathbf{u}_{i+1}$;
- M. means for determining the reciprocal of step K which is $1/\sigma_{i+1}$;
- N. means for storing $1/\sigma_{i+1}$;
- O. means for incrementing i ;
- P. means for conducting steps D through O until $i=p$, where p is the total number of said sources of interest; and
- Q. means for determining \mathbf{y}_{perp} where: $\mathbf{y}_{\text{perp}} = \mathbf{y} - \mathbf{U}(\mathbf{U}^T \mathbf{U})^{-1} \mathbf{U}^T \mathbf{y}$; and wherein said search finger receives an input from said control processor, said input being selected from the group consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i(j)}^\perp$, a product of a projection operator used to remove the k interference signals.

34. The serial receiver for a wireless communication system recited in claim 33, wherein said data parameters are selected from the group consisting of: data streams, time offsets, projection operators or corresponding interference matrices, power information, signal amplitude, and signal polarity.

35. The serial receiver for a wireless communication system recited in claim 34, wherein said data streams are at an intermediate frequency (IF).
36. The serial receiver for a wireless communication system recited in claim 34, wherein said data streams are at base-band (BB) frequency.
37. The serial receiver for a wireless communication system recited in claim 33, wherein said control processor has an output selected from the group consisting of: $y^{(k)}$, a data stream in which k interference signals have been removed; $\prod_{i,j} P_{s_i^{(j)}}^\perp$ — a product of a projection operator that is used to remove the k interference signals; and t_k , time offset for the k th interference signal.
38. The serial receiver for a wireless communication system recited in claim 33, wherein said search finger receives an input from said control processor, said input being an unprocessed measured segment of data.
39. The serial receiver for a wireless communication system recited in claim 33, wherein said search finger receives an input from said control processor, said input being selected from the group consisting of: $y^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$, a product of projection operators used to remove the k interference signals.
40. The serial receiver for a wireless communication system recited in claim 33, wherein said search finger generates an output to said tracking finger.
41. The serial receiver for a wireless communication system recited in claim 40, wherein the search finger output is selected from the group consisting of: time offset and relative power information.

42. The serial receiver for a wireless communication system recited in claim 41, wherein said time offset is an approximation.
43. The serial receiver for a wireless communication system recited in claim 33, wherein said correlator correlates said signal y with a reference signal for s_I , where s_I is the signal of interest.
44. The serial receiver for a wireless communication system recited in claim 33, wherein said correlator correlates said signal $y^{(k)}$ with a reference signal $s_n^{(k)}$.
45. The serial receiver for a wireless communication system recited in claim 33, wherein said correlator correlates said signal $y^{(k)}$ with a reference signal s_n .
46. The serial receiver for a wireless communication system recited in claim 44, wherein said reference signal $s_n^{(k)}$ is produced by multiplying an original reference signal s_n by the k corresponding projection operators.
47. The serial receiver for a wireless communication system recited in claim 44, wherein said reference signal equivalent to $s_n^{(k)}$ is produced by multiplying an original reference signal s_n by the corresponding $(k-1)$ projection operators.
48. A serial receiver for a wireless communication system, said communication system comprising:
- a means for receiving a signal y having data parameters;
 - a control processor; said control processor for receiving said signal y and said data parameters;
 - at least two fingers, said control processor for determining which of said data parameters are sent to which respective fingers, wherein of said fingers, at least one is a search finger and at least one is a tracking finger;

wherein said tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), said CSPE for interference cancellation in the reception of said measured signal;

wherein said CSPE comprises: an apparatus for generating a projection operator and canceling interfering sources from a received signal (\mathbf{y}), said signal comprising \mathbf{s}_i , a signal of the source of interest; $\mathbf{s}_1, \mathbf{s}_2, \mathbf{s}_3, \dots, \mathbf{s}_p$, signals of other interfering sources; and noise (\mathbf{n}); the apparatus comprising:

means for determining a basis vector \mathbf{U} ;

means for storing elements of said basis vector \mathbf{U} ;

means for determining \mathbf{y}_{perp} where: $\mathbf{y}_{\text{perp}} = \mathbf{y} - \mathbf{U}(\mathbf{U}^T \mathbf{U})^{-1} \mathbf{U}^T \mathbf{y}$; and

wherein said search finger receives an input from said control processor, said input being selected from the group consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i^{(j)}}^\perp$, a product of a projection operator used to remove the k interference signals.

49. The serial receiver for a wireless communication system recited in claim 48, wherein said data parameters are selected from the group consisting of: data streams, time offsets, projection operators or corresponding interference matrices, power information, signal amplitude, and signal polarity.

50. The serial receiver for a wireless communication system recited in claim 49, wherein said data streams are at an intermediate frequency (IF).

51. The serial receiver for a wireless communication system recited in claim 49, wherein said data streams are at base-band (BB) frequency.

52. The serial receiver for a wireless communication system recited in claim 48, wherein said control processor has an output selected from the group consisting of: $\mathbf{y}^{(k)}$, a data stream in which k interference signals have been removed; $\prod_{i,j} P_{s_i^{(j)}}^\perp$ – a product of

a projection operator that is used to remove the k interference signals; and t_{k+1} , time offset for the $(k+1)$ th interference signal.

53. The serial receiver for a wireless communication system recited in claim 48, wherein said search finger receives input from said control processor, said input being an unprocessed measured segment of data.

54. The serial receiver for a wireless communication system recited in claim 48, wherein said search finger receives an input from said control processor, said input being selected from the group consisting of: $y^{(k)}$, a data stream in which k interference signals have been removed; and $\prod_{i,j} P_{s_i(j)}^\perp$, a product of a projection operator used to remove the k interference signals.

55. The serial receiver for a wireless communication system recited in claim 48, wherein said search finger generates an output to said tracking finger.

56. The serial receiver for a wireless communication system recited in claim 55, wherein the search finger output is selected from the group consisting of: time offset and relative power information.

57. The serial receiver for a wireless communication system recited in claim 56, wherein said time offset is an approximation.

58. The serial receiver for a wireless communication system recited in claim 48, wherein said correlator correlates said signal y with a reference signal for s_l , where s_l is the signal of interest.

59. The serial receiver for a wireless communication system recited in claim 48, wherein said correlator correlates said signal $y^{(k)}$ with a reference signal $s_n^{(k)}$.

60. The serial receiver for a wireless communication system recited in claim 48, wherein said correlator correlates said signal $y^{(k)}$ with a reference signal s_n .

61. The serial receiver for a wireless communication system recited in claim 59, wherein said reference signal $s_n^{(k)}$ is produced by multiplying a reference signal s_n by the k corresponding projection operators.

62. The serial receiver for a wireless communication system recited in claim 59, wherein said reference signal equivalent to $s_n^{(k)}$ is produced by multiplying a reference signal s_n by the corresponding $(k-1)$ projection operators.

63. The serial receiver for a wireless communication system recited in claim 48, wherein said search finger comprises at least two multipliers, a summer and a comparator.

64. The serial receiver for a wireless communication system recited in claim 63, wherein the first of said multipliers, multiplies a pilot Walsh code with a short code to generate a first reference signal if said Walsh code is non-zero.

65. The serial receiver for a wireless communication system recited in claim 64, wherein said first reference signal is multiplied by the second of said multipliers with a respective orthogonal projection matrix to generate a second reference signal with the interference signal(s) removed.

66. The serial receiver for a wireless communication system recited in claim 65, wherein said second reference signal is multiplied by the third of said multipliers with said signal y to generate an intermediate signal.

67. The serial receiver for a wireless communication system recited in claim 66, wherein said intermediate signal is correlated by summing the product of y and the

second reference signal over a correlation length N in said summer to generate a plurality of summation signals.

68. The serial receiver for a wireless communication system recited in claim 66, wherein said plurality of summation signals are processed by said comparator to select the strongest summation signal.

69. A serial receiver for a wireless communication system, said communication system comprising:

a means for receiving a signal y having data parameters;

a control processor; said control processor for receiving said signal y and said data parameters;

at least two fingers, said control processor for determining which of said data parameters are sent to which respective fingers, wherein of said fingers, at least one is a search finger and at least one is a tracking finger;

wherein said tracking finger comprises a correlator and a Coded Signal Processing Engine (CSPE), said CSPE for interference cancellation in the reception of said signal y ; and

wherein said tracking finger further comprises a tracking loop and a means for signal demodulation.

70. The serial receiver recited in claim 69, wherein said tracking loop comprises a delay-locked loop (DLL) or code offset estimation.

71. The serial receiver recited in claim 69, wherein said tracking loop comprises a phase-locked loop (PLL) or phase estimation.

72. The serial receiver recited in claim 69, wherein said tracking loop comprises a frequency-locked loop (FLL) or frequency estimation.

73. The serial receiver recited in claim 69, wherein the output from said tracking loop is multiplied by a short code spreading sequence by a multiplier to generate a de-spread signal.

74. The serial receiver recited in claim 73, wherein said multiplier also removes the phase from said de-spread signal.

75. The serial receiver recited in claim 73, wherein said de-spread signal is multiplied by a product of a Walsh code associated with a desired channel and a projection matrix P_s^\perp to generate an input signal.

76. The serial receiver recited in claim 75, wherein said input signal is summed by a summer, over one Walsh symbol, to generate a demodulated data signal that is provided to a demodulation module.

77. The serial receiver recited in claim 73, wherein said de-spread signal is provided to a modified Hadamard transform module for demodulating all channels in said finger.

78. The serial receiver recited in claim 77, wherein said modified Hadamard transform module output is the relative signal amplitude of each channel.

79. The serial receiver recited in claim 73, further comprising means for generating an **S** matrix.

80. The serial receiver recited in claim 79, wherein said means for generating said **S** matrix comprises means for determining a method of cancellation.

81. The serial receiver recited in claim 80, wherein said method of cancellation comprises a pre-determined set of channels to be cancelled.

82. The serial receiver recited in claim 80, wherein said method of cancellation comprises a fixed-size subset of channels to be cancelled.

83. The serial receiver recited in claim 80, wherein said method of cancellation comprises a modified Hadamard transform module for dynamically determining the channels to be cancelled.

84. The serial receiver recited in claim 80, wherein said method of cancellation comprises a predetermined value associated with a characteristic of the channels to be cancelled.

85. The serial receiver recited in claim 79, further comprising a means for applying a projection matrix P_s^\perp to said signal y .

86. The serial receiver recited in claim 77, wherein said modified Hadamard transform module comprises a plurality of relative amplitude generation channels, at least one of said relative amplitude generation channels comprising a respective Walsh code or QOF which is multiplied by a projection matrix P_s^\perp and said signal y ; the result of which is summed over a Walsh or QOF symbol by a summer; to generate the channel's amplitude.

87. The serial receiver recited in claim 76, wherein there are 64 channels.

88. A Hadamard transform module, said module comprising:
an input signal y ;
means for splitting said input signal into a plurality of input channels;
a plurality of relative amplitude generation channels, one associated with each of said input channels, wherein at least one of said relative amplitude generation channels comprises a respective Walsh or QOF code which is multiplied by a projection matrix P_s^\perp and said signal y to generate a respective intermediate channel signal; and

a summer for summing said respective intermediate channel signal over a Walsh or QOF symbol to generate the respective channel's amplitude.

89. The transform module recited in claim 88, wherein there are 64 channels.
90. A method for generating an **S** matrix, said method comprising the steps of:
- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
 - B. Determining which input signals will be utilized in the generation of matrix **S**;
 - C. Multiplying each selected input signal with a projection matrix P_s^\perp to generate a column of matrix **S**; and
 - D. Storing each respective column to form matrix **S**.
91. An apparatus for generating an **S** matrix, said apparatus comprising:
- a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
 - a means for determining which input signals will be utilized in the generation of matrix **S**;
 - a means for multiplying each selected input signal with a projection matrix P_s^\perp to generate a column of matrix **S**; and
 - means for storing each respective column to form matrix **S**.
92. The apparatus recited in claim 91, wherein n equals 64.
93. The apparatus recited in claim 91, wherein said means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^\perp or not.
94. A method for generating an **S** matrix, said method comprising the steps of:

- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
 - B. Determining which input signals will be utilized in the generation of matrix **S**;
 - C. Multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal;
 - D. Utilizing relative amplitude information associated with said selected input signals to determine the sign of said selected input signal;
 - E. Multiplying said intermediate signal with its associated sign to generate a column of matrix **S**; and
 - F. Storing each respective column to form matrix **S**.
95. An apparatus for generating an **S** matrix, said apparatus comprising:
a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
a means for determining which input signals will be utilized in the generation of matrix **S**;
a first means for multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal;
a means for utilizing relative amplitude information associated with said input signals to determine the sign of the input signal;
a second means for multiplying said intermediate signal with its associated sign to generate a column of matrix **S**; and
means for storing each respective column to form matrix **S**.
96. The apparatus recited in claim 95, wherein n equals 64.
97. The apparatus recited in claim 95, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^\perp or not.

98. The apparatus recited in claim 95, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said intermediate signal with said sign information or not.

99. A method for generating an **S** matrix, said method comprising the steps of:
- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
 - B. Determining which input signals will be utilized in the generation of matrix **S**;
 - C. Multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal;
 - D. Determining relative amplitude associated with said selected input signals;
 - E. Multiplying said intermediate signal with its associated relative amplitude to generate a column of matrix **S**; and
 - F. Storing each respective column to form matrix **S**.

100. An apparatus for generating an **S** matrix, said apparatus comprising:
- a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
 - a means for determining which input signals will be utilized in the generation of matrix **S**;
 - a first means for multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal;
 - a means for determining relative amplitude associated with said respective input signal;
 - a second means for multiplying said intermediate signal with its associated relative amplitude to generate a column of matrix **S**; and
 - means for storing each respective column to form matrix **S**.

101. The apparatus recited in claim 99 wherein n equals 64.
102. The apparatus recited in claim 100, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^\perp or not.
103. The apparatus recited in claim 100, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said intermediate signal with said relative amplitude information or not.
104. A method for generating an S matrix, said method comprising the steps of:
- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
 - B. Determining which input signals will be utilized in the generation of matrix S ;
 - C. Multiplying each selected input signal with a projection matrix P_s^\perp to generate a column of matrix S ;
 - D. Multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal;
 - E. Utilizing relative amplitude information associated with said selected input signals to determine the sign of said selected input signal;
 - F. Multiplying said intermediate signal with its associated relative amplitude to generate an intermediate column;
 - G. Summing all intermediate columns to generate a column of matrix S ; and
 - H. Storing each respective column of matrix S to form matrix S .
105. An apparatus for generating an S matrix, said apparatus comprising:
- a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;

a means for determining which input signals will be utilized in the generation of matrix **S**;

a first means for multiplying each selected input signal with a projection matrix P_s^\perp to generate a column of matrix **S** and an intermediate signal;

means for utilizing relative amplitude information associated with said selected input signals to determine the sign of said selected input signal;

second means for multiplying said intermediate signal with its associated relative amplitude to generate an intermediate column;

means for summing all intermediate columns to generate a column of matrix **S**;
and

means for storing each respective column of matrix **S** to form matrix **S**.

106. The apparatus recited in claim 105, wherein n equals 64.

107. The apparatus recited in claim 105, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^\perp or not.

108. The apparatus recited in claim 105, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said intermediate signal with said sign information or not.

109. A method for generating an **S** matrix, said method comprising the steps of:

A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;

B. Determining which input signals will be utilized in the generation of matrix **S**;

C. Multiplying each selected input signal with a projection matrix P_s^\perp to generate a column of matrix **S**;

- D. Multiplying each selected input signal with a projection matrix P_s^\perp to generate an intermediate signal;
- E. Determining relative amplitude associated with said selected input signals;
- F. Multiplying said intermediate signal with its associated relative amplitude to generate an intermediate column;
- G. Summing all intermediate columns to generate a column of matrix **S**; and
- H. Storing each respective column of matrix **S** to form matrix **S**.

110. Apparatus recited in claim 109, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^\perp or not.

111. An apparatus for generating an **S** matrix, said apparatus comprising:

a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;

a means for determining which input signals will be utilized in the generation of matrix **S**;

a first means for multiplying each selected input signal with a projection matrix P_s^\perp to generate a column of matrix **S** and an intermediate signal;

means for determining relative amplitude associated with said selected input signals;

second means for multiplying said intermediate signal with its associated relative amplitude to generate an intermediate column;

means for summing all intermediate columns to generate a column of matrix **S**;

and

means for storing each respective column of matrix **S** to form matrix **S**.

112. The apparatus recited in claim 111, wherein n equals 64.

113. The apparatus recited in claim 111, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^\perp or not.

114. The apparatus recited in claim 111, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said intermediate signal with said relative amplitude or not.

115. The serial receiver for a wireless communication system recited in claim 45, wherein said signal y is divided into a y_i and a y_Q channels.

116. The serial receiver recited in claim 115, wherein said search finger comprises at least two multipliers, a summer for each of said y_i and a y_Q channels, and a comparator downstream of said channels.

117. The serial receiver for a wireless communication system recited in claim 116, wherein in said y_i channel the first of said multipliers multiplies a pilot Walsh code with a short code to generate a first reference signal if said Walsh code is non-zero.

118. The serial receiver for a wireless communication system recited in claim 117, wherein said first reference signal is multiplied by the second of said multipliers with a respective orthogonal projection matrix to generate a second reference signal with the interference signal(s) removed.

119. The serial receiver for a wireless communication system recited in claim 118, wherein said second reference signal is multiplied by the third of said multipliers with said signal y_i to generate an intermediate signal.

120. The serial receiver for a wireless communication system recited in claim 119, wherein said intermediate signal is correlated by summing the product of y_i and the

second reference signal over a correlation length N in said summer to generate a first plurality of summation signals.

121. The serial receiver for a wireless communication system recited in claim 120, wherein in said y_Q channel the first of said multipliers multiplies a pilot Walsh code with a short code to generate a first reference signal if said Walsh code is non-zero.

122. The serial receiver for a wireless communication system recited in claim 121, wherein said first reference signal is multiplied by the second of said multipliers with a respective orthogonal projection matrix to generate a second reference signal with the interference signal(s) removed.

123. The serial receiver for a wireless communication system recited in claim 122, wherein said second reference signal is multiplied by the third of said multipliers with said signal y_Q to generate a second intermediate signal.

124. The serial receiver for a wireless communication system recited in claim 123, wherein said second intermediate signal is correlated by summing the product of y_Q and the second reference signal over a correlation length N in said summer to generate a second plurality of summation signals.

125. The serial receiver for a wireless communication system recited in claim 124, wherein said first and second plurality of summation signals are processed by said comparator to select the strongest summation signal.

126. The serial receiver for a wireless communication system recited in claim 69, wherein said signal y is divided into a y_i and a y_Q channels, said channels having an in-phase component (y_i) and a quadrature component (y_Q), respectively.

127. The serial receiver recited in claim 126, wherein said tracking loop comprises a delay-locked loop (DLL) or code offset estimator.

128. The serial receiver recited in claim 126, wherein said tracking loop comprises a phase-locked loop (PLL) or phase estimator.

129. The serial receiver recited in claim 126, wherein said tracking loop comprises a frequency-locked loop (FLL) or frequency estimator.

130. The serial receiver recited in claim 126, wherein the output from said tracking loop in said y_i channel is multiplied by a short code spreading sequence by a multiplier to generate a first de-spread signal.

131. The serial receiver recited in claim 130, wherein said multiplier also removes the phase from said first de-spread signal.

132. The serial receiver recited in claim 130, wherein said first de-spread signal is multiplied by a product of a Walsh code associated with a desired channel and a projection matrix P_s^\perp to generate a first input signal.

133. The serial receiver recited in claim 132, wherein said first input signal is summed by a summer, over one Walsh symbol, to generate a first demodulated data signal that is provided to a demodulation module.

134. The serial receiver recited in claim 130, wherein said de-spread signal is provided to a first modified Hadamard transform module for demodulating all channels in said finger.

135. The serial receiver recited in claim 134, wherein said first modified Hadamard transform module output is the relative signal amplitude of each channel.

136. The serial receiver recited in claim 73, further comprising a first means for generating an **S** matrix.

137. The serial receiver recited in claim 136, wherein said first means for generating said **S** matrix comprises means for determining a first method of cancellation.

138. The serial receiver recited in claim 137, wherein said first method of cancellation comprises a pre-determined set of channels to be cancelled.

139. The serial receiver recited in claim 137, wherein said first method of cancellation comprises a fixed-size subset of channels to be cancelled.

140. The serial receiver recited in claim 137, wherein said first method of cancellation comprises a modified Hadamard transform module for dynamically determining the channels to be cancelled.

141. The serial receiver recited in claim 137, wherein said first method of cancellation comprises a predetermined value associated with a characteristic of the channels to be cancelled.

142. The serial receiver recited in claim 136, further comprising a means for applying a projection matrix P_s^\perp to said in-phase component (y_i).

143. The serial receiver recited in claim 134, wherein said first modified Hadamard transform module comprises a plurality of relative amplitude generation channels, at least one of said relative amplitude generation channels comprising a respective Walsh or QOF code which is multiplied by a projection matrix P_s^\perp and said in-phase component (y_i); the result of which is summed over a Walsh symbol by a summer; to generate the channel's amplitude.

144. The serial receiver recited in claim 126, wherein the output from said tracking loop in said y_D channel is multiplied by a short code spreading sequence by a multiplier to generate a second de-spread signal.

145. The serial receiver recited in claim 144, wherein said multiplier also removes the phase from said second de-spread signal.

146. The serial receiver recited in claim 144, wherein said second de-spread signal is multiplied by a product of a Walsh code associated with a desired channel and a projection matrix P_s^\perp to generate a second input signal.

147. Apparatus recited in claim 146, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^\perp or not.

148. The serial receiver recited in claim 146, wherein said second input signal is summed by a summer, over one Walsh or QOF symbol, to generate a second demodulated data signal is provided to a demodulation module.

149. The serial receiver recited in claim 144, wherein said second de-spread signal is provided to a second Hadamard transform module for demodulating all channels in said finger.

150. The serial receiver recited in claim 149, wherein said second modified Hadamard transform module output is the relative signal amplitude of each channel.

151. The serial receiver recited in claim 150, further comprising a second means for generating a **S** matrix.

152. The serial receiver recited in claim 151, wherein said second means for generating said S matrix comprises means for determining a second method of cancellation.

153. The serial receiver recited in claim 152, wherein said second method of cancellation comprises a pre-determined set of channels to be cancelled.

154. The serial receiver recited in claim 152, wherein said second method of cancellation comprises a fixed-size subset of channels to be cancelled.

155. The serial receiver recited in claim 152, wherein said second method of cancellation comprises a modified Hadamard transform module for dynamically determining the channels to be cancelled.

156. The serial receiver recited in claim 152, wherein said second method of cancellation comprises a predetermined value associated with a characteristic of the channels to be cancelled.

157. The serial receiver recited in claim 152, further comprising a means for applying a projection matrix P_s^\perp to said quadrature component (y_Q).

158. The serial receiver recited in claim 149, wherein said second modified Hadamard transform module comprises a plurality of relative amplitude generation channels, at least one of said relative amplitude generation channels comprising a respective Walsh code which is multiplied by a projection matrix P_s^\perp and said quadrature component (y_Q); the result of which is summed over a Walsh symbol by a summer; to generate the channel's amplitude.

159. The serial receiver recited in claim 148, wherein there are 64 channels.

160. A modified Hadamard transform module, said module comprising:
an input signal y , said signal having an in-phase component (y_i) and a quadrature component (y_Q);
means for splitting said in-phase component (y_i) into a first plurality of input channels;
a first plurality of relative amplitude generation channels, one associated with each of said first input channels, wherein at least one of said relative amplitude generation channels comprises a respective Walsh code which is multiplied by a projection matrix P_s^\perp and said in-phase component (y_i) to generate a respective first intermediate channel signal;
a first summer for summing said respective first intermediate channel signal over a Walsh symbol to generate the respective channel's amplitude;
means for splitting said quadrature component (y_Q) into a second plurality of input channels;
a second plurality of relative amplitude generation channels, one associated with each of said second input channels, wherein at least one of said relative amplitude generation channels comprises a respective Walsh code which is multiplied by a projection matrix P_s^\perp and said quadrature component (y_Q) to generate a respective second intermediate channel signal; and
a second summer for summing said respective second intermediate channel signal over a Walsh symbol to generate the respective channel's amplitude.
161. Apparatus recited in claim 160, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^\perp or not.
162. The transform module recited in claim 160, wherein there are 64 channels.
163. A method for generating an S matrix, said S matrix having an in-phase and a quadrature component, said method comprising the steps of:

- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);
- B. Determining which in-phase components of said input signals will be utilized in the generation of matrix S_I ;
- C. Multiplying each in-phase component of said selected input signal with a projection matrix $P_{s_I}^\perp$ to generate a column of matrix S_I ;
- D. Storing each respective column to form matrix S_I ;
- E. Determining which quadrature components of said input signals will be utilized in the generation of matrix S_Q ;
- F. Multiplying each quadrature component of said selected input signal with a projection matrix $P_{s_Q}^\perp$ to generate a column of matrix S_Q ; and
- G. Storing each respective column to form matrix S_Q .

164. Apparatus recited in claim 163, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_I}^\perp$ or not.

165. Apparatus recited in claim 163, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_Q}^\perp$ or not.

166. An apparatus for generating an S matrix, said S matrix having an in-phase and a quadrature component, said apparatus comprising:

a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);

a means for determining which in-phase components of said input signals will be utilized in the generation of matrix S_I ;

a first means for multiplying each in-phase component of said selected input signal with a projection matrix $P_{s_i}^\perp$ to generate a column of matrix S_I ;

means for storing each respective column to form matrix S_I ;

a means for determining which quadrature components of said input signals will be utilized in the generation of matrix S_Q ;

a second means for multiplying each quadrature component of said selected input signal with a projection matrix $P_{s_q}^\perp$ to generate a column of matrix S_Q ; and

means for storing each respective column to form matrix S_Q .

167. The apparatus recited in claim 166, wherein n equals 64.

168. The apparatus recited in claim 166, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_i}^\perp$ or not.

169. The apparatus recited in claim 166, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_q}^\perp$ or not.

170. A method for generating an S matrix, said S matrix having an in-phase and a quadrature component, said method comprising the steps of:

A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);

B. Determining which in-phase components of said input signals will be utilized in the generation of matrix S_I ;

C. Multiplying each in-phase component of said selected input signal with a projection matrix $P_{s_i}^\perp$ to generate an in-phase intermediate signal;

- D. Utilizing relative amplitude information associated with said in-phase component of said selected input signals to determine the sign of said selected in-phase component of said input signal;
- E. Multiplying said in-phase intermediate signal with its associated sign to generate a column of matrix \mathbf{S}_I ;
- F. Storing each respective column to form matrix \mathbf{S}_I ;
- G. Determining which quadrature components of said input signals will be utilized in the generation of matrix \mathbf{S}_Q ;
- H. Multiplying each quadrature component of said selected input signal with a projection matrix $P_{s_q}^\perp$ to generate a quadrature intermediate signal;
- I. Utilizing relative amplitude information associated with said quadrature component of said selected input signals to determine the sign of said selected quadrature component of said input signal;
- J. Multiplying said quadrature intermediate signal with its associated sign to generate a column of matrix \mathbf{S}_Q ; and
- K. Storing each respective column to form matrix \mathbf{S}_Q .

171. Apparatus recited in claim 170, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_r}^\perp$ or not.

172. Apparatus recited in claim 170, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_q}^\perp$ or not.

173. An apparatus for generating an \mathbf{S} matrix, said \mathbf{S} matrix having an in-phase and a quadrature component, said apparatus comprising:

a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);

a means for determining which in-phase components of said input signals will be utilized in the generation of matrix \mathbf{S}_I and \mathbf{S}_Q ;

a first means for multiplying each in-phase component of said selected input signal with a projection matrix $P_{s_1}^\perp$ to generate an in-phase intermediate signal;

a means for utilizing relative amplitude information associated with said in-phase component of said input signals to determine the sign of the in-phase component of said input signal;

a second means for multiplying said in-phase intermediate signal with its associated sign to generate a column of matrix \mathbf{S}_I ;

means for storing each respective column to form matrix \mathbf{S}_I ;

a third means for multiplying each quadrature component of said selected input signal with a projection matrix $P_{s_2}^\perp$ to generate a quadrature intermediate signal;

a means for utilizing relative amplitude information associated with said quadrature component of said input signals to determine the sign of the quadrature component of said input signal;

a fourth means for multiplying said quadrature intermediate signal with its associated sign to generate a column of matrix \mathbf{S}_Q ; and

means for storing each respective column to form matrix \mathbf{S}_Q .

174. The apparatus recited in claim 173, wherein n equals 64.

175. The apparatus recited in claim 173, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_1}^\perp$ or not.

176. The apparatus recited in claim 173, wherein said third means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_2}^\perp$ or not.

177. The apparatus recited in claim 173, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said in-phase intermediate signal with said sign information or not.

178. The apparatus recited in claim 173, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said quadrature intermediate signal with said sign information or not.

179. A method for generating an **S** matrix, said **S** matrix having an in-phase and a quadrature component, said method comprising the steps of:

- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);
- B. Determining which input signals will be utilized in the generation of matrix **S_I**;
- C. Multiplying each in-phase component of said selected input signal with a projection matrix $P_{s_i}^\perp$ to generate an in-phase intermediate signal;
- D. Determining relative amplitude associated with said in-phase component of said selected input signals;
- E. Multiplying said in-phase intermediate signal with its associated relative amplitude to generate a column of matrix **S_I**;
- F. Summing each column of matrix **S_I** to generate a composite column;
- G. Storing said composite column to form matrix **S_I**;
- H. Determining which input signals will be utilized in the generation of matrix **S_Q**;
- I. Multiplying each quadrature component of said selected input signal with a projection matrix $P_{s_i}^\perp$ to generate a quadrature intermediate signal;
- J. Determining relative amplitude associated with said quadrature component of said selected input signals;

- K. Multiplying said quadrature intermediate signal with its associated relative amplitude to generate a column of matrix S_Q ;
- L. Summing each column of matrix S_Q to generate a composite column; and
- M. Storing said composite column to form matrix S_Q .

180. An apparatus for generating an S matrix, said S matrix having an in-phase and a quadrature component, said apparatus comprising:

a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals and where each input signal W has an in-phase component (W_I) and a quadrature component (W_Q);

a means for determining which input signals will be utilized in the generation of matrix S_I and S_Q ;

a first means for multiplying each in-phase component of said selected input signal with a projection matrix $P_{s_i}^\perp$ to generate an in-phase intermediate signal;

a means for determining relative amplitude associated with said in-phase component of said respective input signal;

a second means for multiplying said in-phase intermediate signal with its associated relative amplitude to generate a column of matrix S_I ;

first means for summing each column of matrix S_I to generate a first composite column;

first means for storing said first composite column to form matrix S_I ;

a third means for multiplying each quadrature component of said selected input signal with a projection matrix $P_{s_q}^\perp$ to generate a quadrature intermediate signal;

a means for determining relative amplitude associated with said quadrature component of said respective input signal;

a fourth means for multiplying said quadrature intermediate signal with its associated relative amplitude to generate a column of matrix S_Q ;

means for summing each column of matrix S_Q to generate a second composite column; and

means for storing said second composite column to form matrix S_Q .

181. The apparatus recited in claim 180, wherein n equals 64.
182. Apparatus recited in claim 180, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_i}^\perp$ or not.
183. Apparatus recited in claim 180, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_i}^\perp$ or not.
184. The apparatus recited in claim 180, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_i}^\perp$ or not.
185. The apparatus recited in claim 180, wherein said third means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix $P_{s_q}^\perp$ or not.
186. The apparatus recited in claim 180, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said in-phase intermediate signal with said relative amplitude information or not.
187. The apparatus recited in claim 180, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said quadrature intermediate signal with said relative amplitude information or not.
188. A method for generating an S matrix, said method comprising the steps of:

- A. Receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;
- B. Determining which input signals will be utilized in the generation of matrix S ;
- C. Multiplying each of said selected input signals with a projection matrix P_s^\perp to generate an intermediate signal;
- D. Determining relative amplitude associated with said component of said selected input signals;
- E. Multiplying said intermediate signal with its associated relative amplitude to generate a column of matrix S ;
- F. Summing each column of matrix S to generate a composite column; and
- G. Storing said composite column to form matrix S .

189. An apparatus for generating an S matrix, said apparatus comprising:

a means for receiving a plurality of input signals W_1 through W_n , where n represents the number of input signals;

a means for determining which input signals will be utilized in the generation of matrix S ;

a first means for multiplying each of said selected input signals with a projection matrix P_s^\perp to generate an intermediate signal;

a means for determining relative amplitude associated with said respective input signal;

a second means for multiplying said intermediate signal with its associated relative amplitude to generate a column of matrix S ;

first means for summing each column of matrix S to generate a first composite column; and

first means for storing said first composite column to form matrix S .

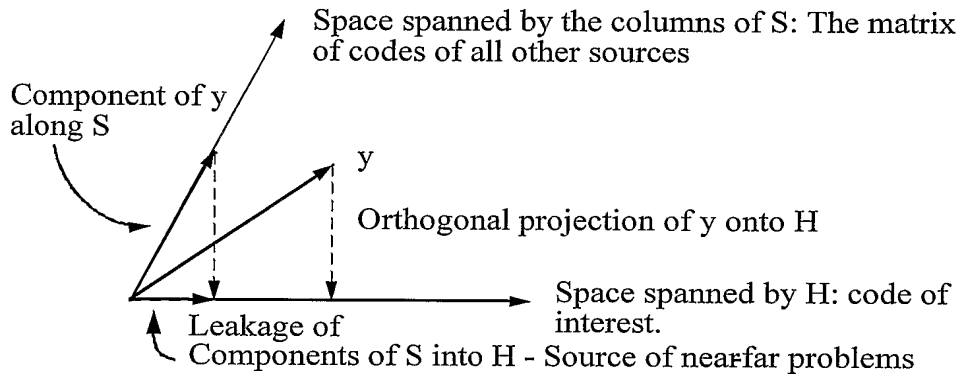
190. The apparatus recited in claim 189, wherein n equals 64.

191. The apparatus recited in claim 189, wherein said first means for multiplying further comprises a selective engagement means for determining whether to multiply the respective selected input signal with said projection matrix P_s^{-1} or not.

192. The apparatus recited in claim 189, wherein said second means for multiplying further comprises a selective engagement means for determining whether to multiply said intermediate signal with said relative amplitude information or not.

1/18

FIG. 1



(PRIOR ART)

FIG. 2

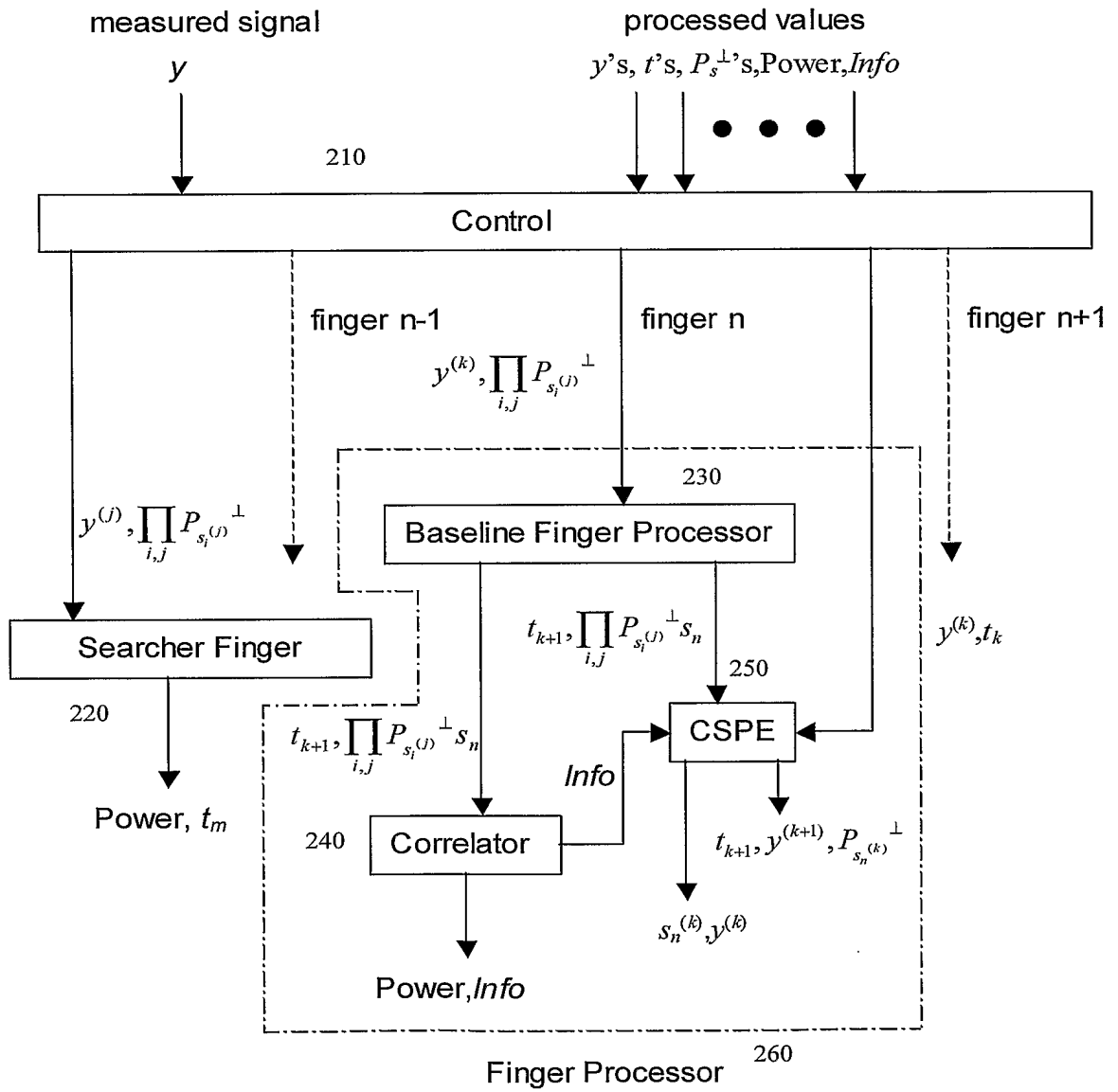
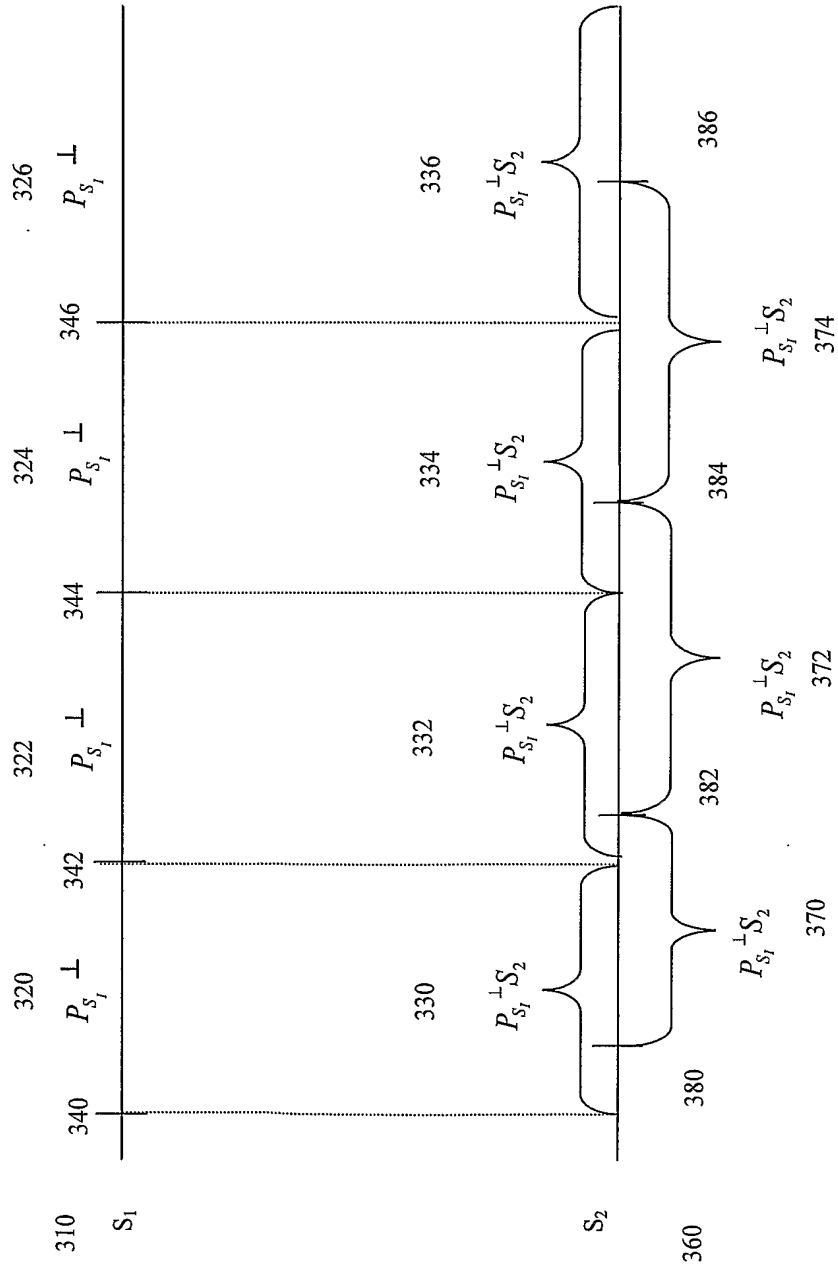
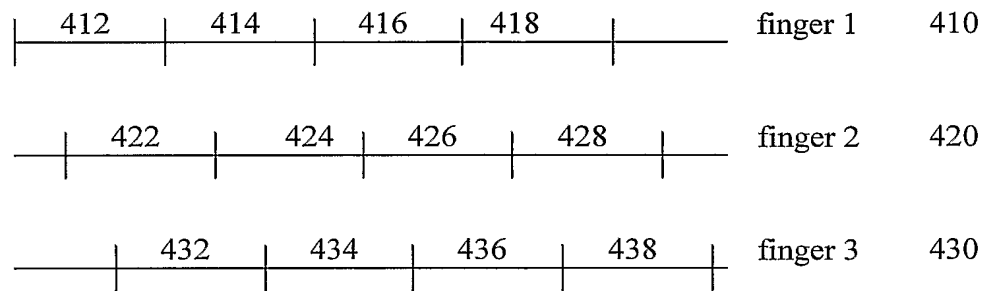


FIG. 3
Applying Projection Operator to a Reference Signal



4/18

FIG. 4

The vertical lines are used to denote segments and occur at symbol boundaries

FIG. 5
Forward Link Receiver

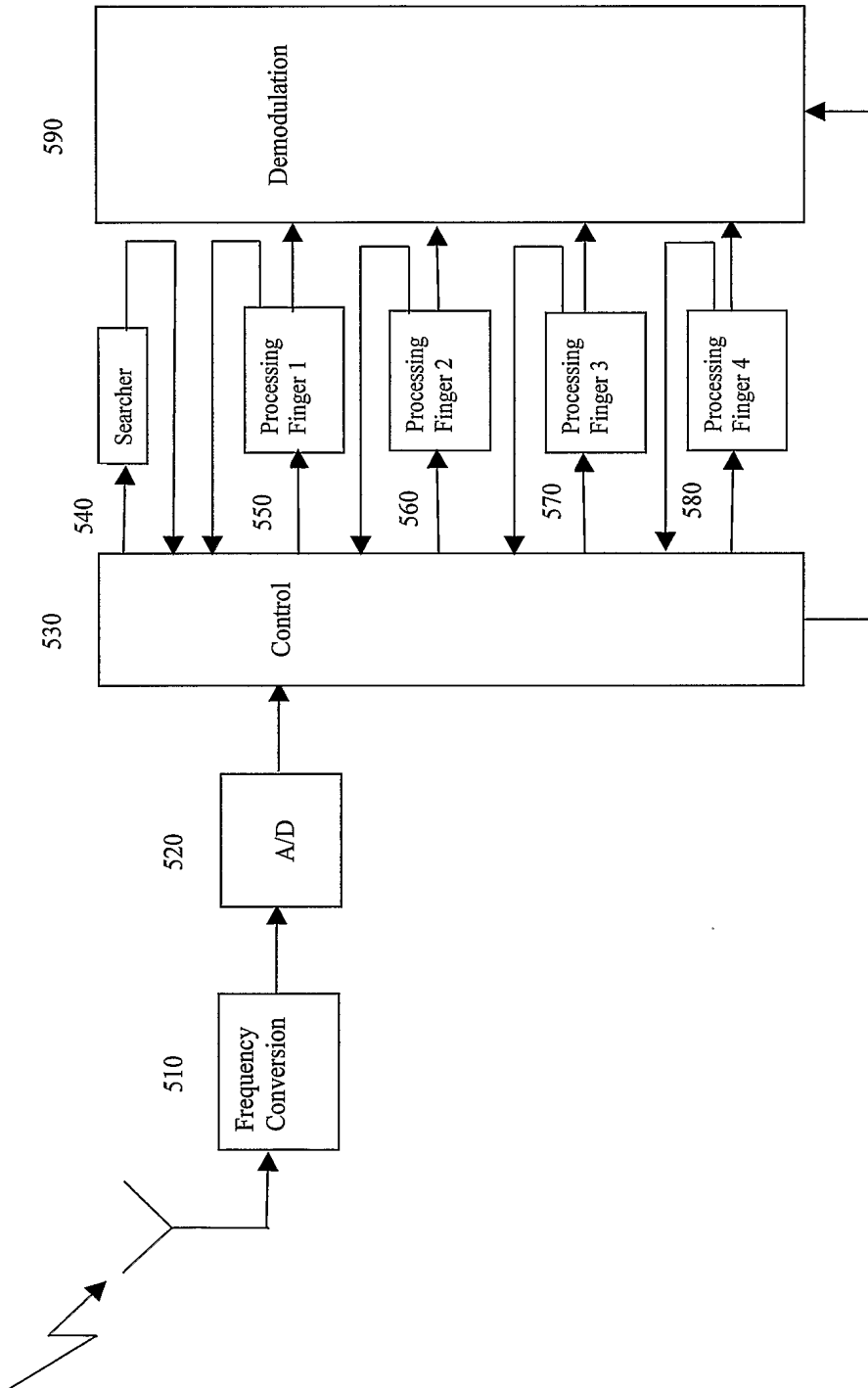
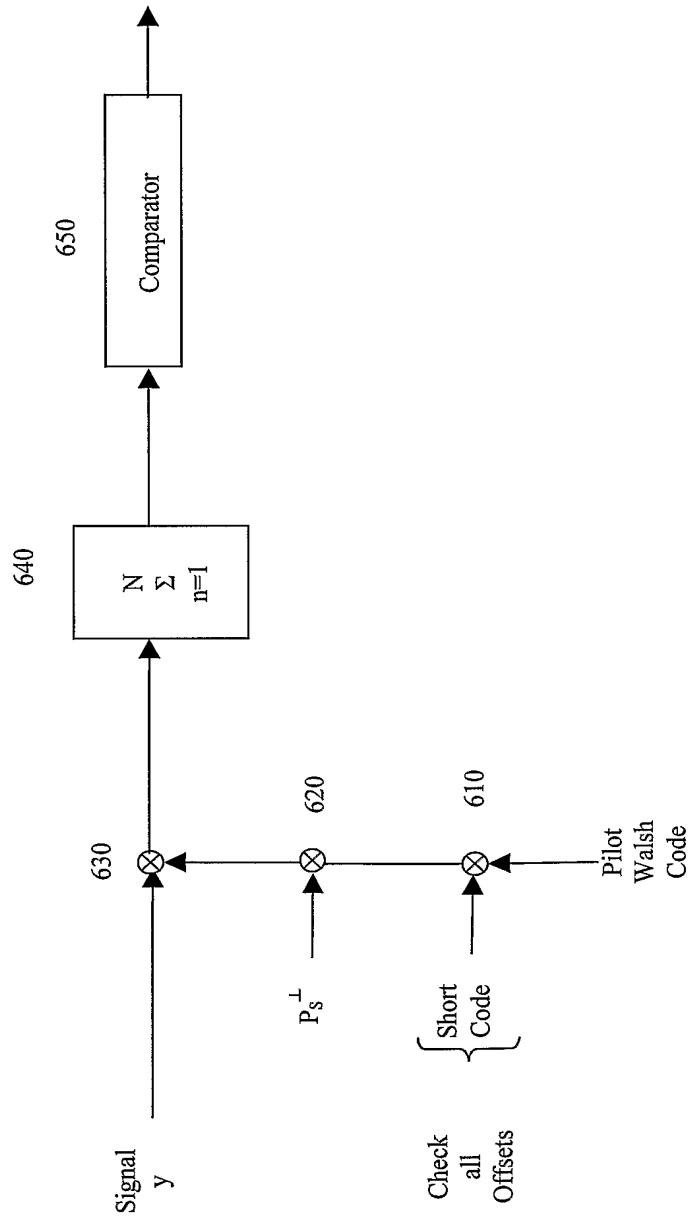
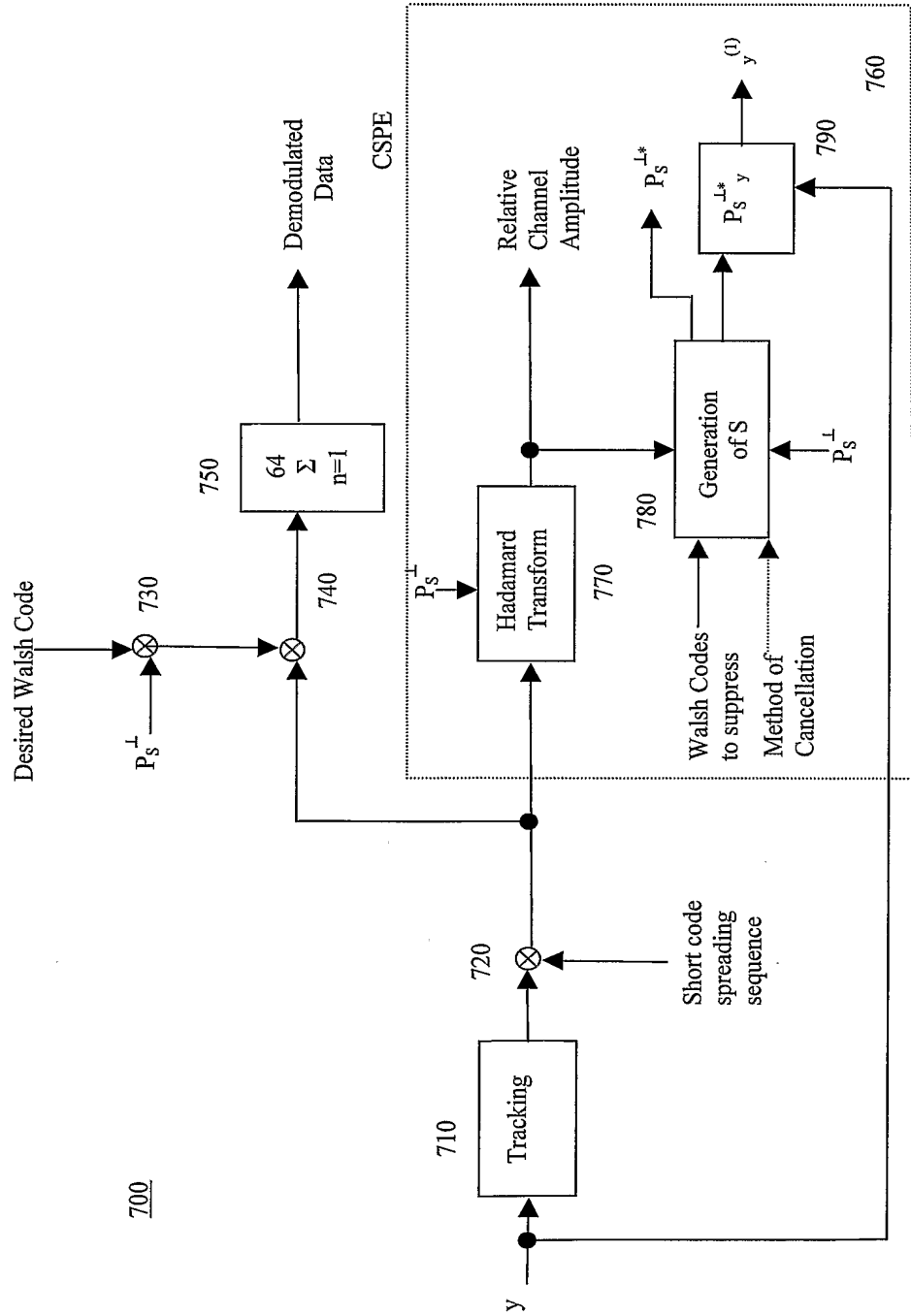


FIG. 6
IS-95 Searcher



600

FIG. 7
IS-95 Processing Finger



700

710

720

750

740

770

780

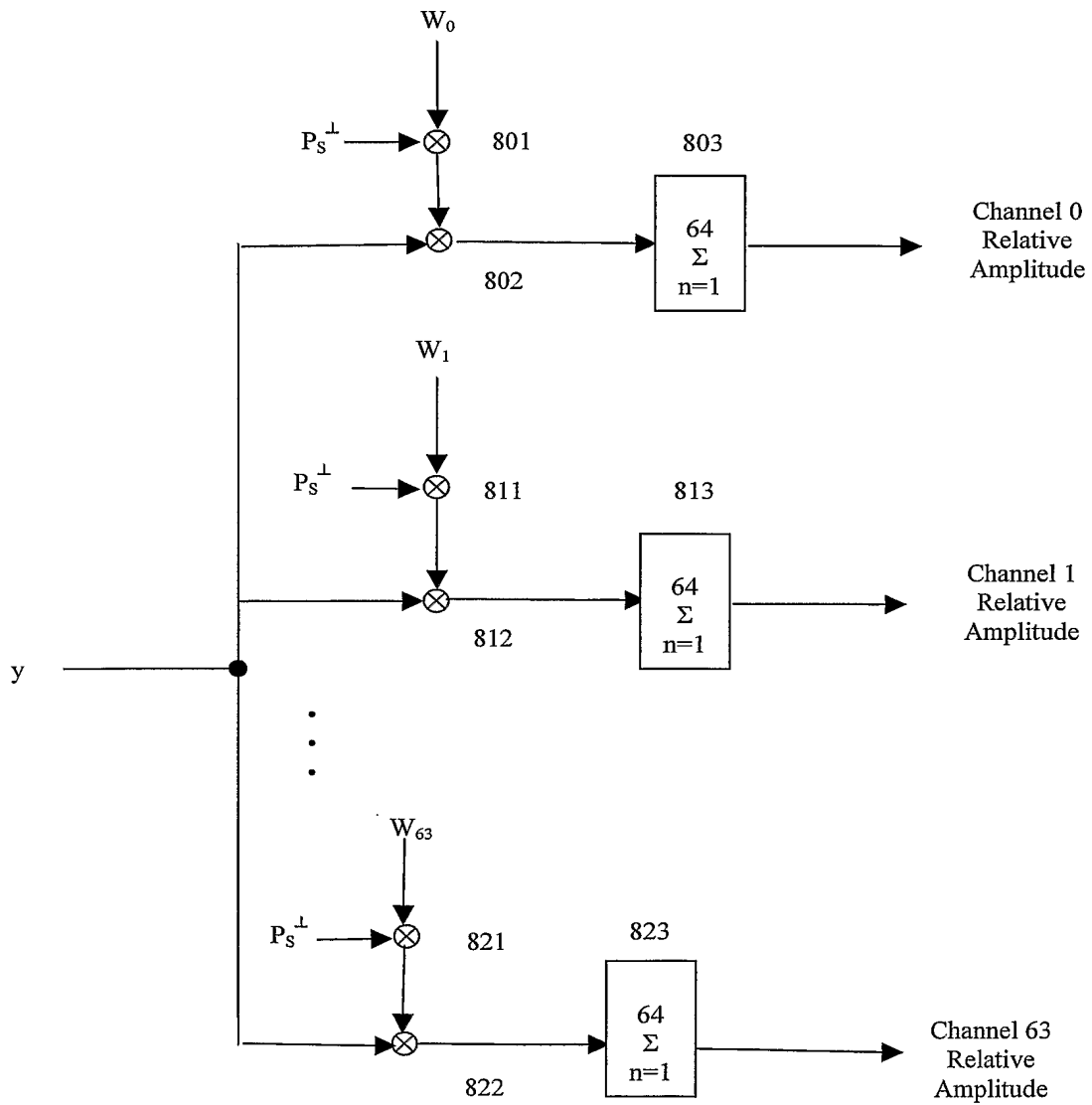
790

760

8/18

FIG. 8

IS-95 Hadamard Transform



9/18

FIG. 9
IS-95 Generation of S Matrix

No information:

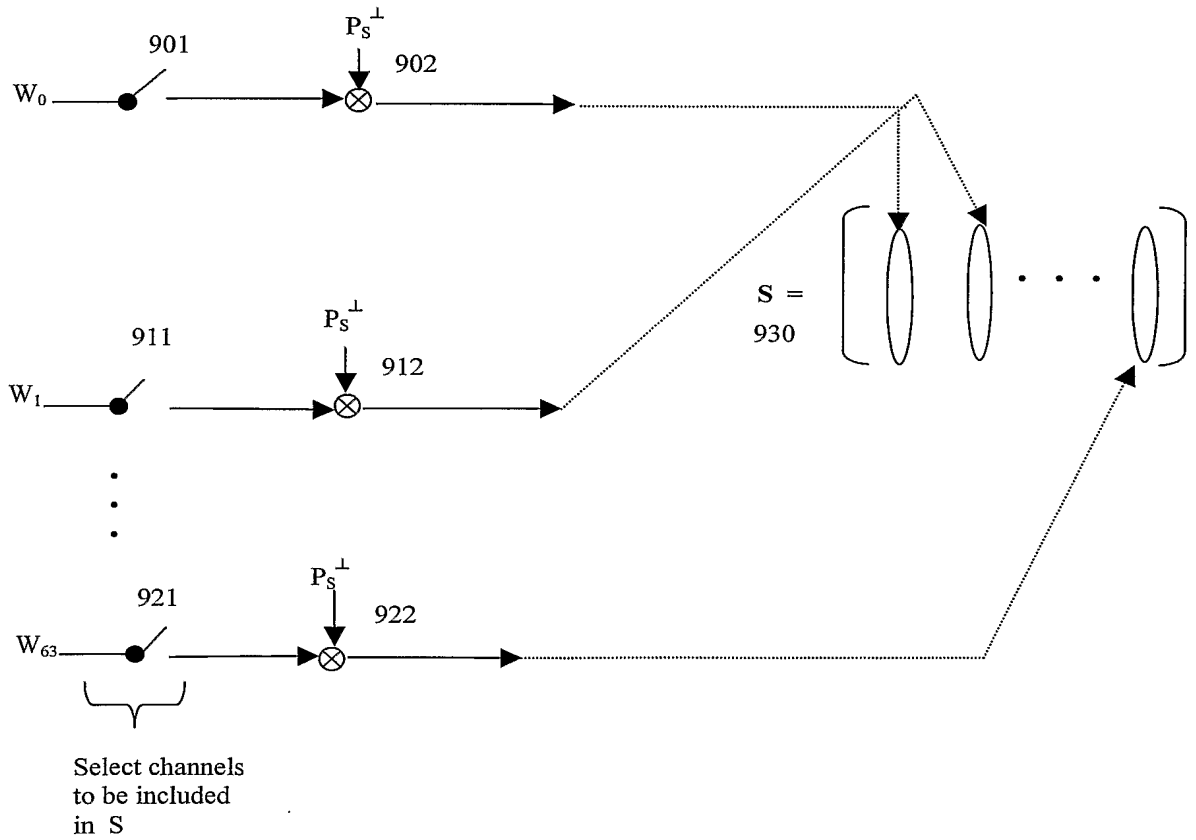


FIG. 10
IS-95 Generation of S Matrix

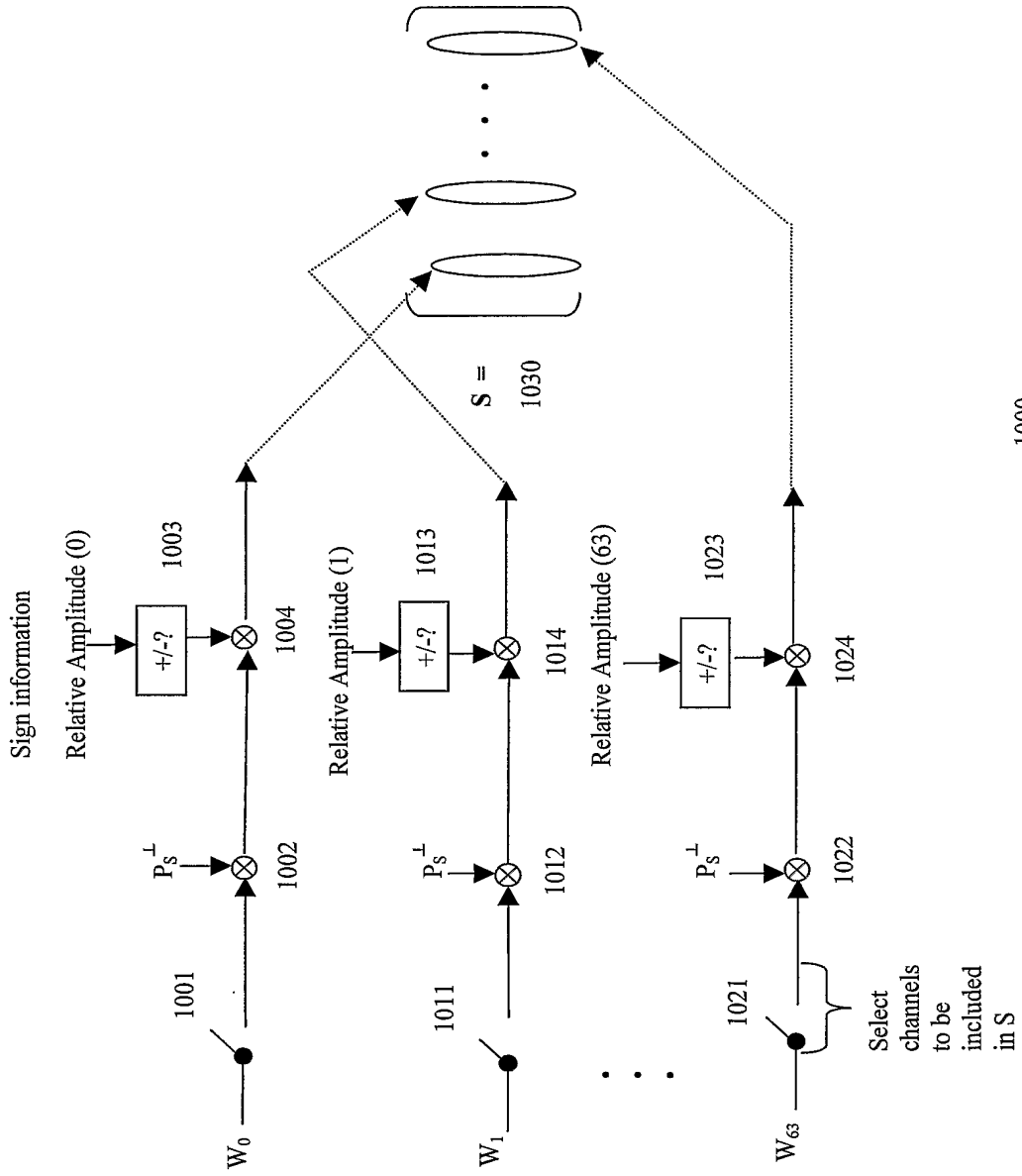
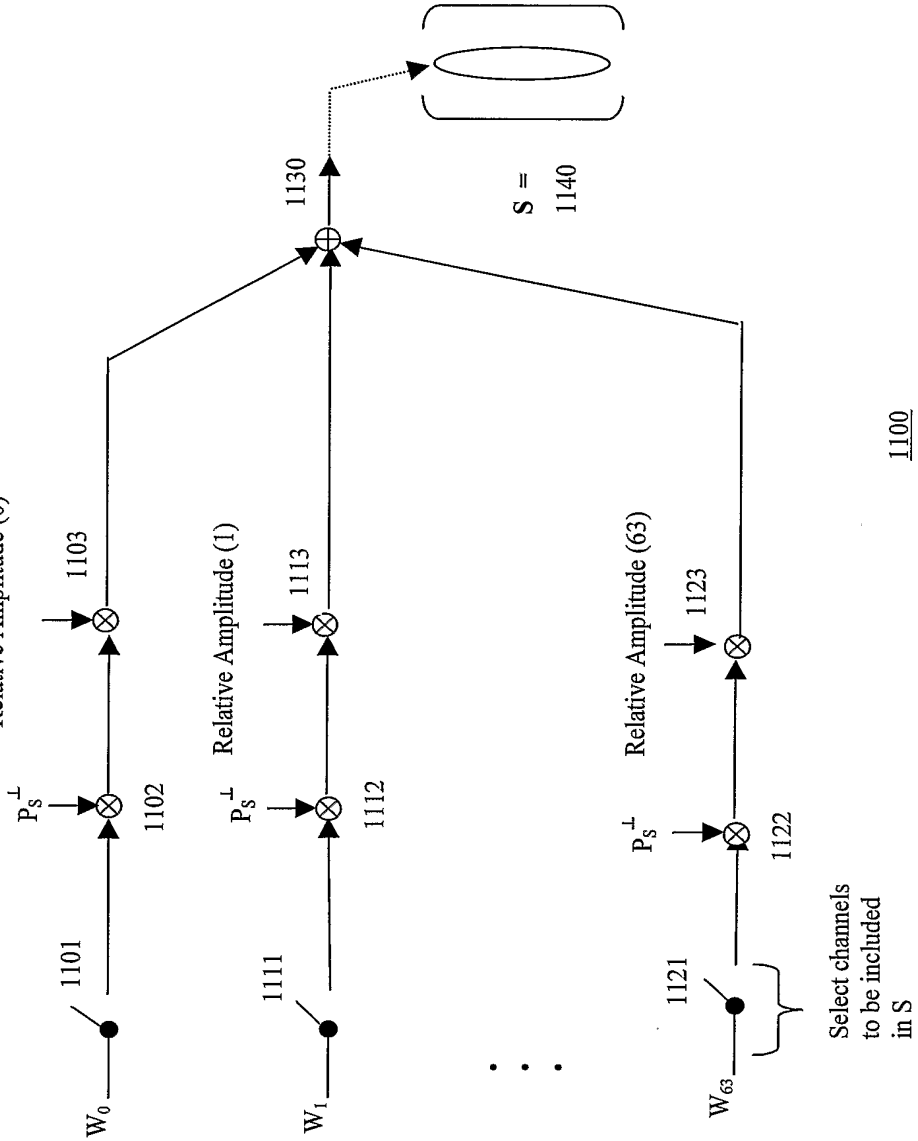


FIG. 11
IS-95 Generation of S Matrix

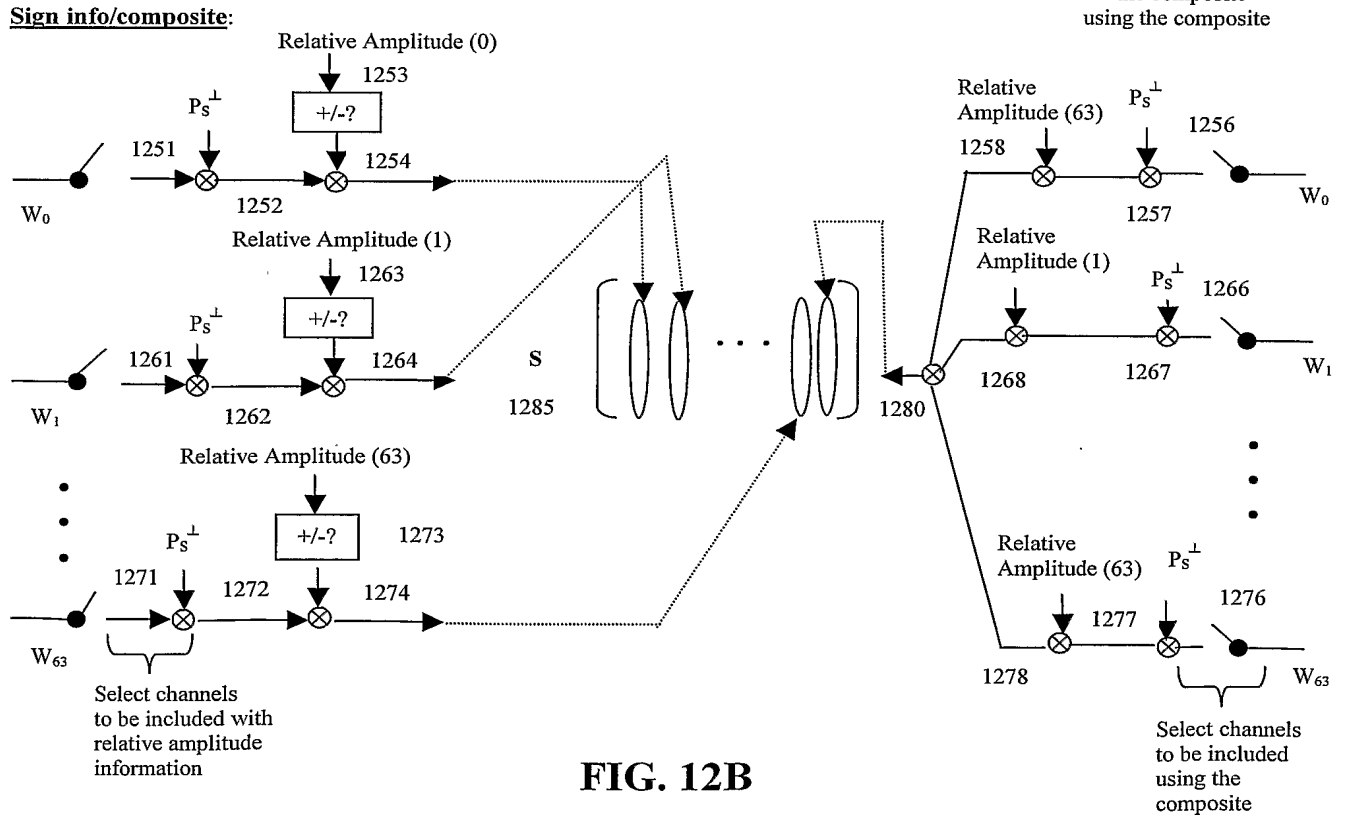
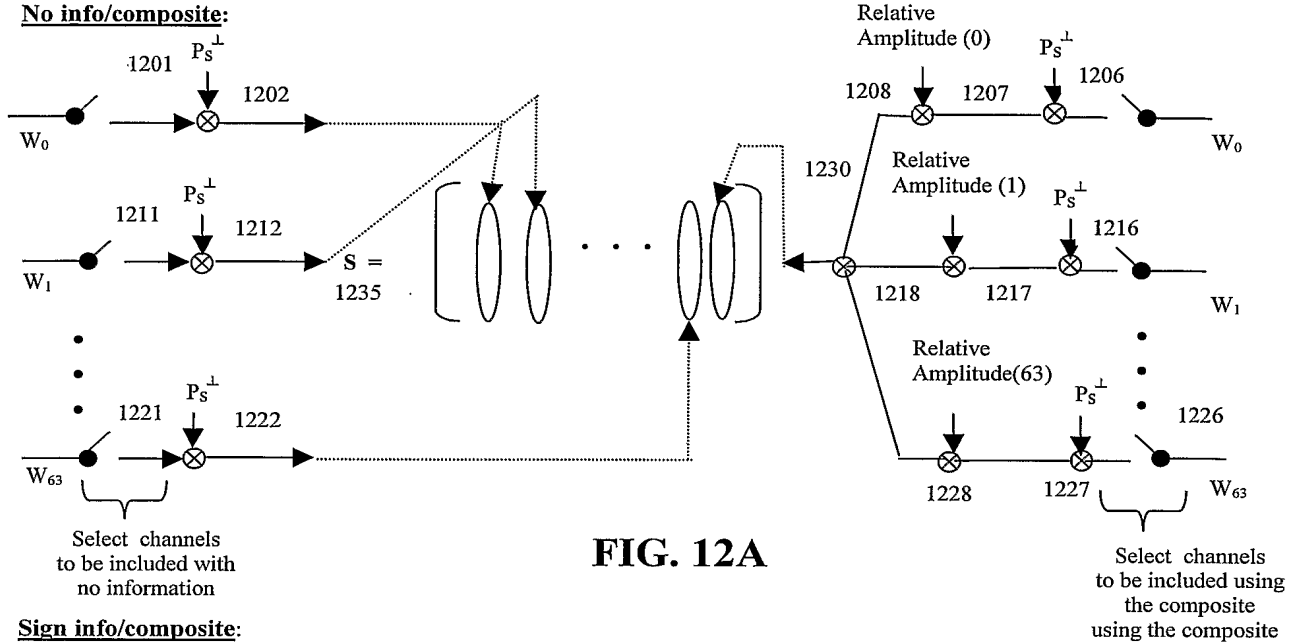
Composite: Relative Amplitude Information

Relative Amplitude (0)



IS-95 Generation of S Matrix

Examples of Combination Methods



13/18

FIG. 13
CDMA2000 Searcher

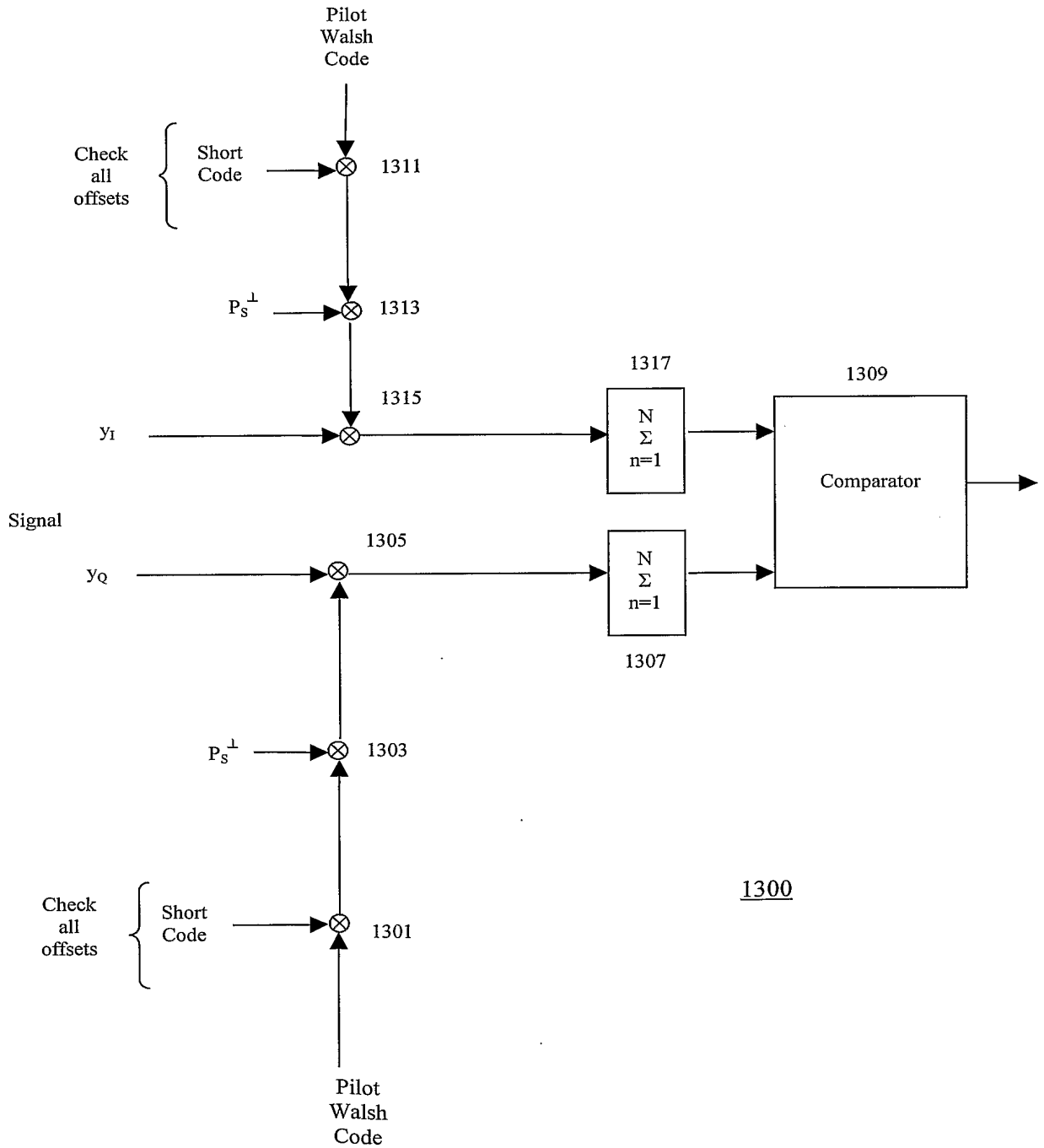
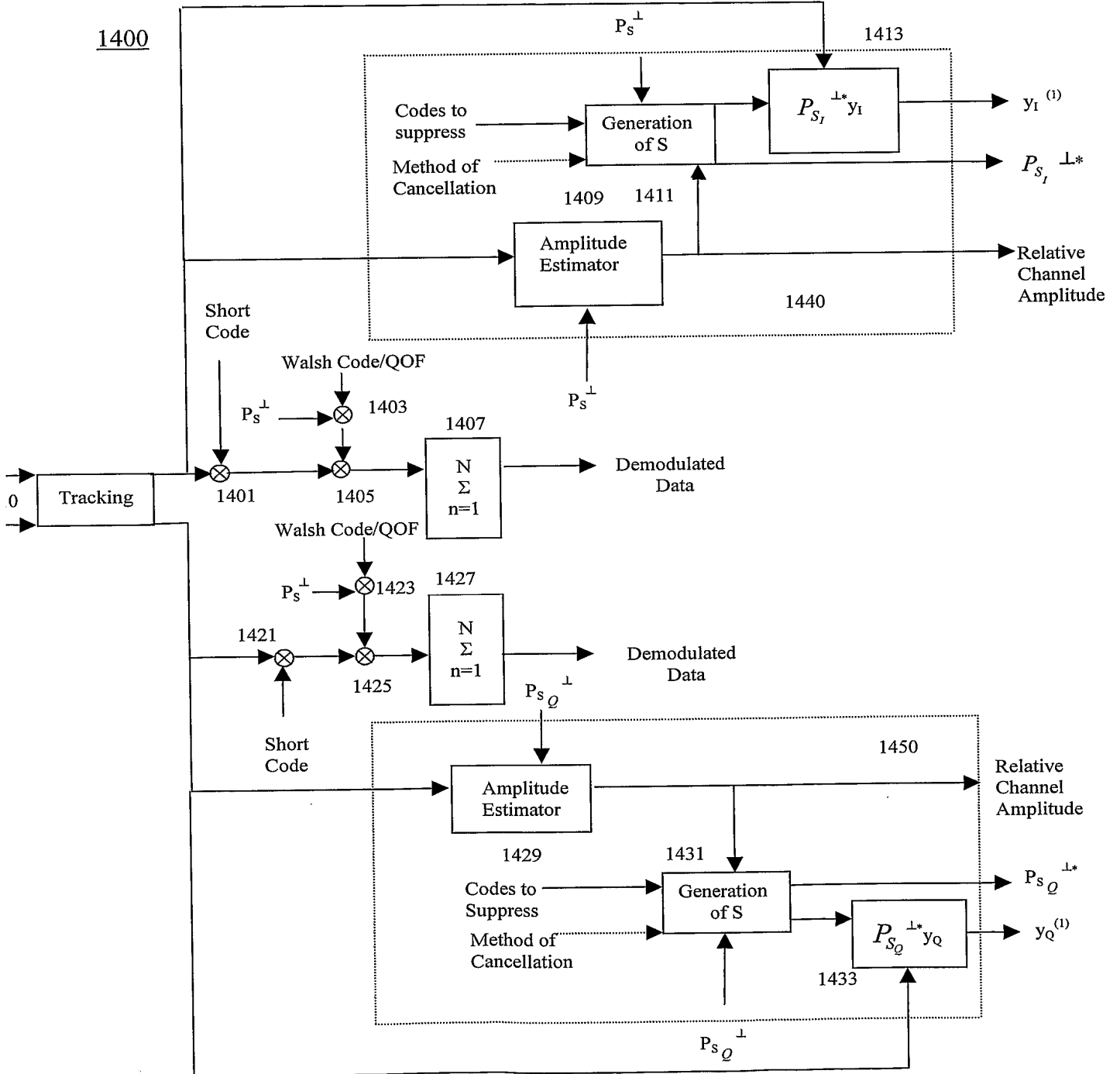


FIG. 14

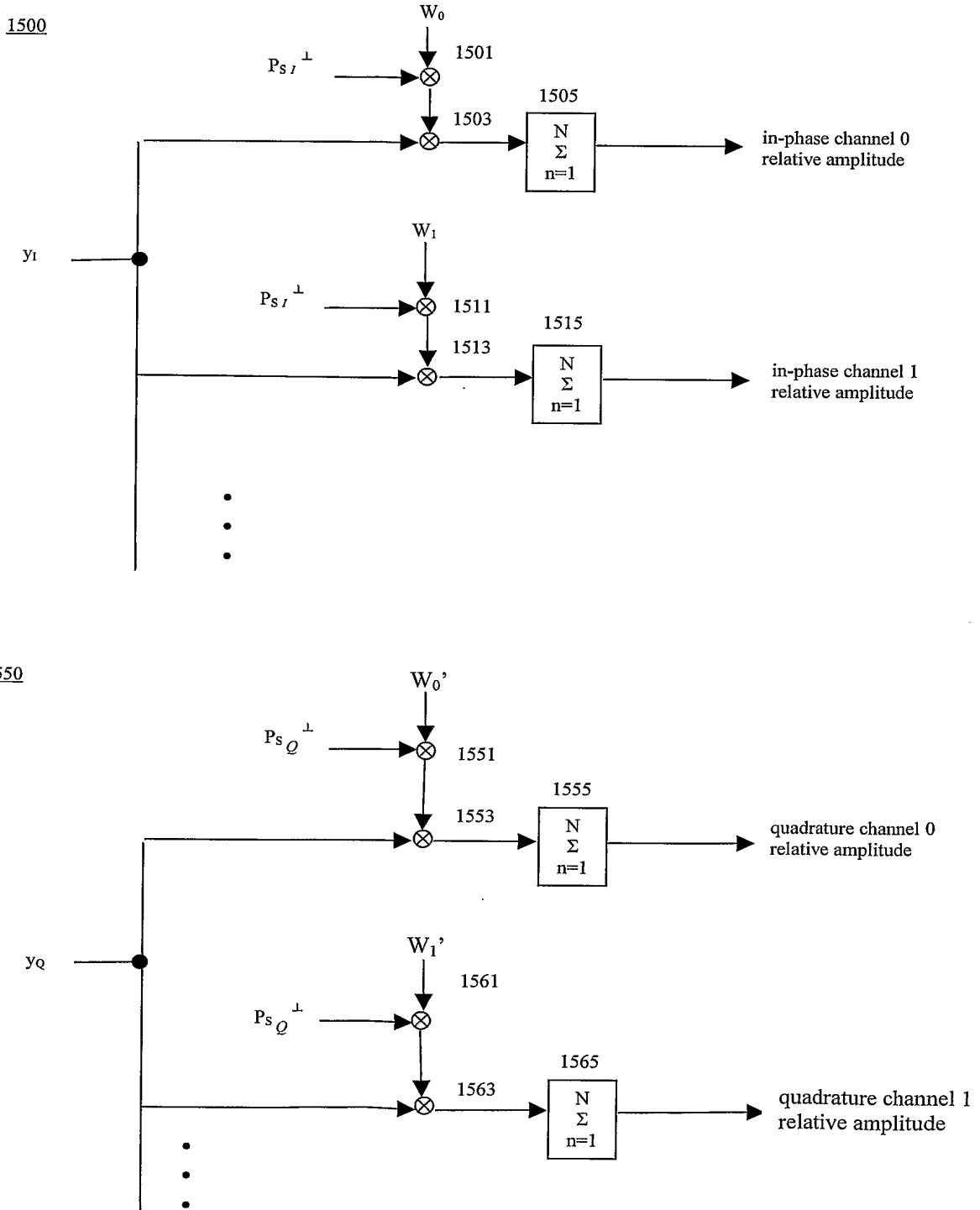
CDMA2000 Processing Finger



15/18

FIG. 15

CDMA2000 Amplitude Estimator



16/18

CDMA2000 Generation of S Matrices

No Information:

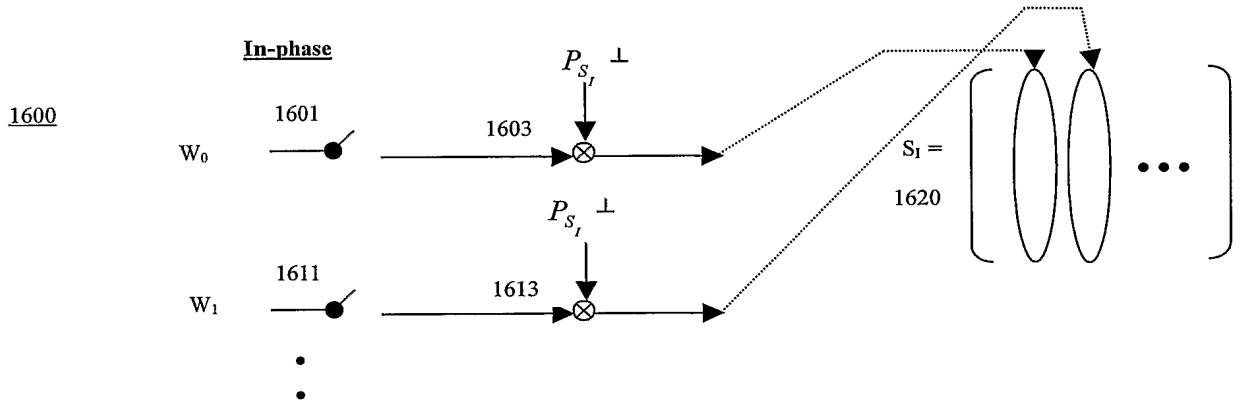


FIG. 16A

Select channels
to be included
in S_1

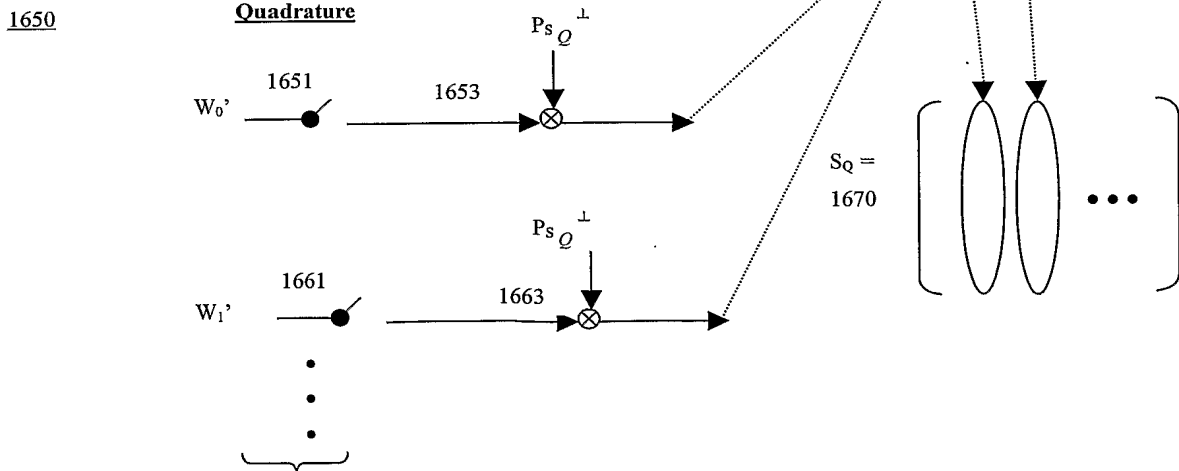


FIG. 16B

Select channels
to be included
in S_Q

17/18

CDMA2000 Generation of S Matrices

Sign information:

1700

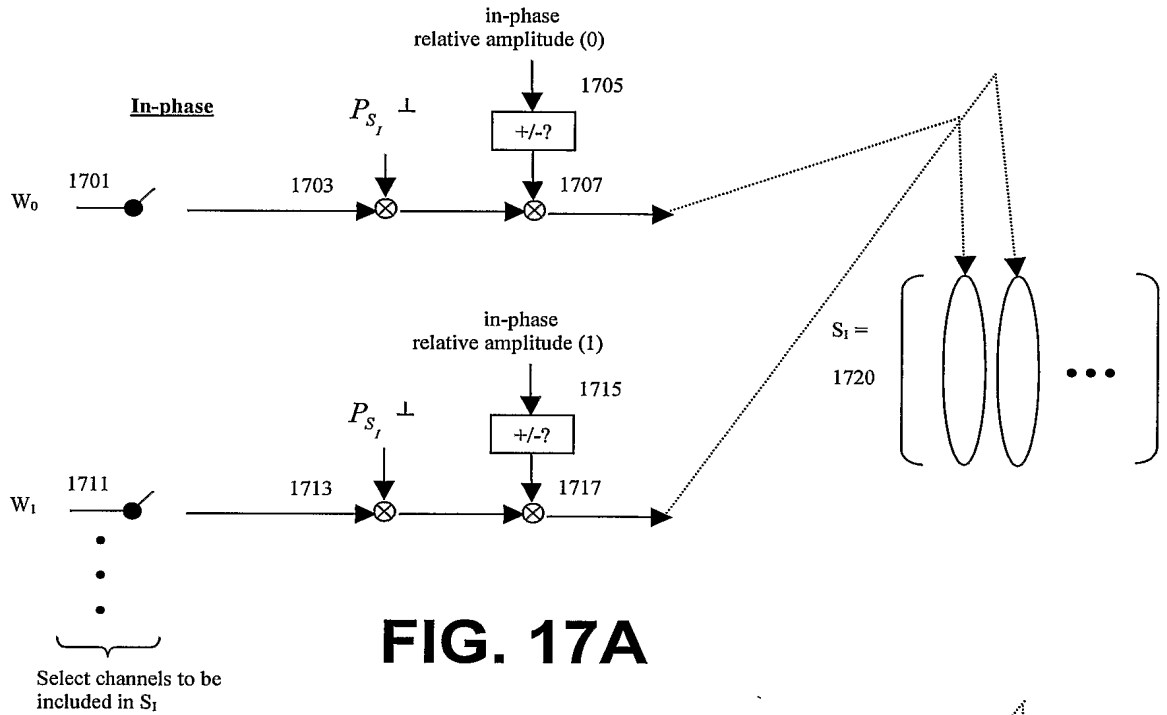


FIG. 17A

1750

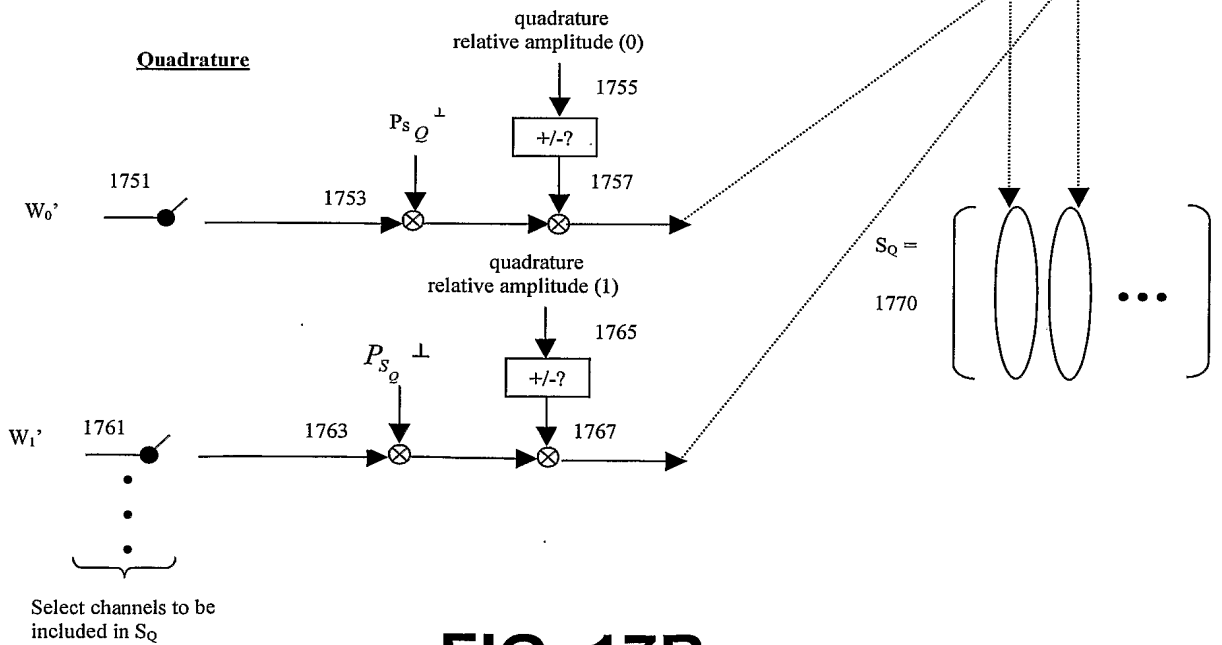


FIG. 17B

CDMA2000 Generation of S Matrices

Composite: Relative Amplitude Information

